DOCUMENT RESUME

ED 305 226 SE 050 404

AUTHOR	Ellington, E. C., Comp.
TITLE	Better Science: Approaches to Teaching and Learning. Curriculum Guide 4.
INSTITUTION	School Curriculum Development Committee, London (England).; Secondary Science Curriculum Review, London (England).
SPONS AGENCY	Association for Science Education, Cambridge (England).
REPORT NO	ISBN-0-435-54821-2
PUB DATE	87
NOTE	66p.; For the curriculum review see SE 050 400; for other curriculum guides in this series see SE 050 401-412.
AVAILABLE FROM	Heinemann Educational Books, Inc., Halley Court, Jordan Hill, Oxford OX2 8EJ, United Kingdom ($44.40 English pounds per set).
PUB TYPE	Reports - Descriptive (141) -- Viewpoints (120) -- Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Curriculum Development; *Educational Improvement; Elementary Secondary Education; Foreign Countries; Instructional Development; Instructional Improvement; *Science Curriculum; Science Departments; *Science Education; Science Instruction; Science Teachers; *Secondary School Science; *Teacher Effectiveness
IDENTIFIERS	*United Kingdom

ABSTRACT

This publication is one in a series of 12 giving the recommendations that were made for a broad and balanced education program in science for young people. Following the introduction, section one discusses content and rationale and the need for an extended range of approaches, basic assumptions about teaching and learning, the purposes of school science and the translation of these into an effective model for teaching. Section two deals with the curriculum model and its operation in practice. Section three presents exemplars based on ideas discussed in the first two sections. Section four covers monitoring students' progress and teachers' effectiveness. The last section shows a reorientation of the teacher/student relationship and a list of recommendations for achieving this. A list of references is included. (RT)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED305226

SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE:

Approaches to teaching and learning

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Eluned Harries

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Curriculum Guides

SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE:
Approaches to teaching and learning

Curriculum Guide 4

Compiled by E.C. Ellington

Heinemann Educational Books/Association for Science Education
for the School Curriculum Development Committee

The Secondary Science Curriculum Review has run from 1981–1986 (Phases 1 and 2), with a dissemination phase (Phase 3) from 1986–1989.

The Review operates under the aegis of the School Curriculum Development Committee and is supported by the Association for Science Education. In addition, it receives or has received support from the Department of Education and Science, local education authorities, the Schools Council (Phase 1), the Northern Ireland Council for Educational Development (Phase 2), the Health Education Council (Phase 2), industry (particularly British Petroleum), the Department of Trade and Industry and the Independent Broadcasting Authority.

Acknowledgements

The ideas presented in this Curriculum Guide are not only the result of the work of SSCR groups. Their production has also relied on considerable discussion in, and on the collective wisdom of, the SSCR Central Team:

Beverley Bell (CLIS Project Coordinator 1984–85), Di Bentley (Research and Development Officer, Health and Science Education 1983–86), Paula Bower (Information Officer 1984–86), Christine Ditchfield (Southern Regional Project Officer), Dave Ebbutt (Evaluation Officer 1983–86), Kate Ellington (North West Regional Project Leader 1983–86), John Heaney (Midlands Regional Project Officer), Joseph Hornsby (North Regional Project Officer), Ruth Jarman (Northern Ireland Regional Project Leader 1983–84), Jeff Kirkham (Director from 1986; Director Designate 1985–86), Anna Larter (Project Administrator), Mick Michell (Director 1985–86; Deputy Director 1982–85), Val Oldham (CLIS Project Coordinator 1985–86), Denis Stewart (Regional Project Officer Wales & West Midlands from 1986; Northern Ireland Regional Project Leader 1984–86), Jeff Thompson (Chairman, SSCR Steering Committee), Mike Watts (Anglia Regional Project Leader 1983–86), Dick West (Director 1981–85) and Cathy Wilson (ASE/SSCR Liaison Officer).

The compiler of this Guide is grateful to the following: Helen Bambrough, researcher for this guide; the writing team for this Guide: Di Bentley, Andrew Cooper, Trevor Cross, Bob Cummings, Julia Dick, Dave Gibson, Phil Munson, Phil Naylor, Roy Phipps, Anita Pride, Mike Watts and Norma White; and the steering group for this guide: Fred Archenhold, Mike Beveridge, Andy Cooper, Stan Cooper, Rosalind Driver, Dave Ebbutt, Jim Eglen, Val Emmett, Brian Harris, Phil Hayes, Hugh Kelly, Ray Leigh, Roy Phipps, Anita Pride, Joan Solomon, Ray West and Norma White; Dave Wallwork, who provided information on a 'problem-solving day' for Section 4.

The compiler also thanks the readers: Fred Archenhold, Rosalind Driver, John Nellist and Joan Solomon; and Pat Burdett, Pat Elkington, Bob Finch, Ron Lewin, P. McBride, Brenda Prestt, Jean Rudduck and Geoffrey Shillito.

Special thanks are extended to BBC Educational Broadcasting, to Rod Smith and Peter Wilkinson for their advice and organisation of in-service training courses for members of the writing team.

The venture would not have been possible to operate without teacher writers at residential workshops and we are deeply grateful to Bob Finch at ICI for his support, encouragement and financial assistance.

Thanks go to all SSCR convenors of local working groups and other teachers who sent in exemplar materials and have provided such a rich and diverse resource bank of learning approaches.

Thanks also to go Anna Larter and Sylvia Barnes, whose wisdom and administrative skills have been immensely valuable in the preparation of this Guide.

The publishers would like to acknowledge permission to use material included in the exemplars. Details are provided at the end of each exemplar.

Heinemann Educational Books Ltd
22 Bedford Square, London WC1B 3HH

LONDON EDINBURGH MELBOURNE AUCKLAND
SINGAPORE KUALA LUMPUR NEW DELHI
IBADAN NAIROBI JOHANNESBURG
PORTSMOUTH (NH) KINGSTON

The Association for Science Education,
College Lane, Hatfield, Herts

ISBN 0 435 54821 2
© SCDC Publications 1987
First published 1987

Typeset by Castlefield Press, Wellingborough, Northamptonshire
Printed and bound in Great Britain by
Scotprint Ltd, Musselburgh

Contents

Introduction 1

SECTION ONE **Context and rationale** 2
Introduction 2
Why use a wide range of learning approaches? 2
What does science contribute to the general education of young people? 3
How can the purposes of school science be translated into an effective model for classroom teaching? 4

SECTION TWO **Selecting an approach** 6
Introduction 6
How can approaches be selected to implement the interactive curriculum model? 6
How can learning approaches best be selected in order to meet specific aims and purposes? 7
Which learning outcomes? 7
Using the instrument: an example 8

SECTION THREE **The 'ideas bank' of exemplars** 10
Introduction 10
What is meant by 'approaches'? 10
Which approach do we refer to? 10
The layout of the exemplars 12
The exemplars 13
Science through Health Education 13
Scientists Thinking and Working With Air — a Whole-Day Approach 17
Salt across the World — Multicultural Experiences through Science 21
Computer-Assisted Learning for Biologists 25
Science through a Technological and Vocational Context 29
Science Visits out of School — Environmental Field Excursions 33
Science Visits out of School — Meteorology 37
Particles Matter 41
Yoghurt and You 45
Electricity, Electronics and Microelectronics Technology Project 49

SECTION FOUR **Monitoring students' progress and teachers' effectiveness** 53
Introduction 53
What are the benefits to students? 53
Initiating problem solving 53
What can be learned from their comments? 54
What are the experiences of other teachers using new approaches? 54
What methods could be used to collect the evaluation evidence? 55
The teacher as 'action researcher' 55

SECTION FIVE **Ways and means** 57

References 59

Foreword

This is the fourth in a collection of twelve Curriculum Guides from the Secondary Science Curriculum Review, published jointly by Heinemann Educational Books and the Association for Science Education.

A Directory of Resources and a book, *Better Science: Making it happen*, which tries to set the Review's recommendations in the context of the whole school, will appear at the same time as the Guides. These will, when taken with earlier and forthcoming SSCR publications, including those from local groups, constitute the recommendations which the Review is making towards a broad and balanced science education for all the young people in our schools. The series title, 'Better Science' is thus both apposite and self-explanatory. It is hoped that the current phase of the Review (1986–89) will achieve successful imple-mentation of the recommendations.

But what is the status of these new publications, apart from reflecting the formal approval and support of our major sponsors, the School Curriculum Development Committee and the Association for Science Education? From what sources have the recommendations within them emanated? Those readers unfamiliar with the history of the SSCR will find it explained within the Guides; but most will be aware that it set out as a project which tried to involve fully the practising teacher in the development of solutions to the problem of science for all. Thus, although the Guides have been compiled principally by the Central Team of the Review, they draw on the work of thousands of teachers in working groups over the past four years. Although the work of many of the groups is referred to in the Guides, it is not possible to refer to it all. In the *Directory of Resources* readers will find details of what many of these groups have produced. The writing of these Guides, however, would not have been possible without the groups' existence and the Review Central Team hopes that the content of the Guides truly reflects their work. Thus the pronoun 'we', used within them, often reflects the view, gleaned over five years of consultation, of the practising teachers involved with the Review. On other occasions it can represent the views of the SSCR as constituted by the Central Team and Steering Committee and it is hoped that particular usage will be apparent from the context.

Jeff Kirkham
Mick Michell
Jeff Thompson
Dick West
(SSCR Curriculum Guide Editors)

Introduction

This Curriculum Guide has been prepared by members of the SSCR Central Team in collaboration with ten experienced practising teachers involved in SSCR research and development activities. The case study exemplars to be found in Section 3 were sent in response to the paper *Approaches to learning and teaching: proposals for consultation* (**0.1**) by Convenors of SSCR Local Working Groups and by other teachers with substantial expertise in a wide range of learning approaches. In writing this guide on teaching and learning it is recognised that the needs and purposes of readers will vary. There are, however, a number of central issues – areas of concern and importance to all teachers – which take the form of such questions as:

- Why use an extended range of approaches?
- How will students benefit from learning through a greater variety of approaches?
- What are the purposes of education and what is the contribution of science education to the whole school curriculum?
- What are the different approaches to teaching and learning which have been tried and tested by teachers?
- How may an approach best be selected to provide for the required learning opportunities?
- How can students' progress in learning be monitored?
- How can teachers' effectiveness in providing enhanced learning opportunities/outcomes be evaluated?

These questions are addressed in the following sections. Section 1: *Context and rationale* discusses the need for an extended range of approaches, basic assumptions about teaching and learning, the purposes of school science and the translation of these into an effective model for teaching. Section 2: *Selecting an approach* is concerned with the curriculum model and its operation in practice. Section 3 presents an *Ideas bank of exemplars*. The ideas discussed in Sections 1 and 2 thus form the rationale - the basis for selecting from the exemplars in Section 3. They also constitute an overview of some of the strengths and weaknesses of current science teaching and indicate how those strengths could be used for extending our repertoire of learning approaches. Section 4 considers *Monitoring students' progress and teachers' effectiveness* while in Section 5: *Ways and means* we advocate a reorientation of the teacher/student relationship and list our recommendations both for achieving this and putting into effect the approaches to teaching and learning we have offered.

SECTION ONE

Context and rationale

Introduction

This section attempts to set the scene for issues about learning and teaching through an explanation of:

1 the evidence pointing to a need for an extended range of learning approaches and some assumptions concerning learning and teaching;
2 the contribution of science to the general education of young people;
3 suggestions concerning the means of translating the purpose of school science into an effective model for teaching.

Why use a wide range of learning approaches?

As science teachers, we are well versed in managing learning in a variety of different styles and modes. The nature of practical work, and experiments performed by students as individuals or in small groups, has enabled us to see the benefits of activities which are not heavily teacher-directed, i.e. didactic. Such activities require the active participation of students in the learning process, for example when youngsters formulate and test hypotheses, design experiments, and evaluate their results.

Precisely what youngsters and teachers do in practical sessions, and the outcomes in terms of understanding of scientific concepts, the development of experimental skills and scientific attitudes, has been an issue of concern to several agencies for some time. The findings of Her Majesty's Inspectorate (HMI), the Assessment of Performance Unit (APU) and of the Children's Learning in Science Project (CLISP) are of particular interest here.

HMI has been aware of the influence of teaching styles on the quality of students' learning for a number of years (**1.1**) and have found that, where there is an emphasis on didactic approaches through an overdependence on teacher talk and chalk, recipe-type worksheets and low level 'problem solving', the opportunities for students to reach their own decisions or to rely on their own judgements are severely restricted. It may even be possible for students to attend a number of lessons without understanding the purpose of the work or of the experiments. Some students who become socialised to having low expectations of themselves and who are infrequently invited to become active participants in the learning process may feel powerless and become passive and unenthusiastic. Other students may resist this form of socialisation and become frustrated and disruptive in school.

In a more recent publication (**1.2**) HMI stresses the need for a wide range of teaching techniques and active learning activities which emphasise the development of skills, attitudes and concepts as well as presentation of factual knowledge.

> *For example, physical skills cannot be acquired through theoretical exposition alone and conceptual understanding does not come with dictated notes. The aim to develop curiosity, creativity and independent thought will not be achieved by teaching which relies excessively on instruction and didactic methods.* (**1.2**,p.35)

This view is reiterated in a further paper (**1.3**) produced as a review of published reports.

> *Good teachers need a variety of approaches and patterns of working, and the flexibility to call upon several different strategies in the space of one lesson . . . Pupils of any age need a satisfying balance between oral, practical and written tasks providing scope for extended discussion as well as for sustained writing of many kinds.*

The Assessment of Performance Unit (APU) Science Project has conducted five annual large-scale surveys during 1980–84 at ages 11, 13 and 15 to determine the performance of students on six categories of science activities. The test items focus on the methods and processes of science and on the applications of conceptual knowledge. The series of *Reports for Teachers* (**1.4–1.6**) are invaluable in that they review the strengths and weaknesses of childrens' performance on these APU test items. One report (**1.6**), in its discussion of the findings from 1980–84, suggests that the majority of students aged 15 can demonstrate knowledge of the procedures of science, including relatively complex tasks of planning and performing investigations. The large majority of students aged 15 *can* read straightforward information from graphs, tables and charts, read simple scales and make straightforward measurements, follow instructions, and perform basic observation and interpretation tasks. It was also found that when presented with a problem to solve in a practical situation, the majority of students can translate the problem into a relevant practical activity and set up the conditions necessary to find a solution. Nevertheless and in spite of our success at working in a practical mode

with our students, there is still room for improvement. In one APU report (**1.6**) it was concluded that:

> *The small proportion of pupils who gave adequate written accounts of an experimental design has been noted. Opportunities for pupils to design experiments, or comment critically on the design of others, are not often given in science lessons . . . If skills of experimental design are seen to be important, then opportunities need to be given to develop these skills explicitly.*

Students' weaknesses were primarily in the area of applying science concepts learned in one context to other situations and in problem solving through paper and pencil test items *without the opportunity to interact with the apparatus*. Some implications of the APU surveys are set out in Box 1:

- that teachers should focus on practical problem-solving in order to present all students with a broad view of science within which the majority can demonstrate success;
- that there should be a reduction in the number of concepts covered for most students in order to create time for the development of the scientific processes;
- that youngsters should be given more time to become familiar with the concepts they do meet and opportunities to explore them in a variety of situations.

Box 1 *Some implications of the APU surveys*

This points towards the need for an extended range of approaches through which concepts and methods can be explored and understood.

The work of the Childrens' Learning in Science Project (CLISP) raises some additional issues. The project has produced a series of reports following an analysis of students' extended responses to APU test items which have been supplemented by interviews designed to explore youngsters' understanding of some of the scientific ideas in the questions (**1.7 – 1.11**). Members of the CLISP team have identified a range of misconceptions and 'alternative theories' held by students. It was found that even in areas which receive considerable attention in teaching, such as the particulate nature of matter, and even in the case of the most academically able students in Physics and Chemistry groups, only a minority of the students used the accepted scientific ideas with confidence (**1.7**).

Other work undertaken in the United Kingdom and elsewhere (**1.12**, **1.13**) points to the same conclusions and implications. Youngsters' scientific beliefs are not only used in the interpretation of everyday experience in preference to school-taught theories, but they may be firmly held and not readily changed in the face of contradictory results or evidence from experiments and demonstrations in science lessons. The research has implications:

- for the language and terminology used in lessons;
- for the ideas we may expect students to develop;
- for the production of science teaching materials;
- for the teaching methods used.

This again points to the need for a variety of approaches through which a students' beliefs may be effectively challenged such that they become more closely aligned to those of accepted science.

Improving students' performance is neither a quick nor a straightforward process, nor can it be guaranteed. What is certain is that teaching for different skills and understanding requires different methods and approaches. Which method works for particular individuals or groups at any one time is a matter for exploration, judgement and experience.

What does science contribute to the general education of young people?

As young people begin to develop independence of their immediate family environment, their social experience widens through interaction with friends and society. Learning is a normal human activity which happens very much as a matter of course, but schooling offers a unique opportunity to widen the experience of individuals in a social context. Schools can be thought of as 'mini-societies' in which students may practise the skills and knowledge in preparation for citizenship and personal fulfilment in 'safe' conditions. Schooling, moreover, offers opportunities for youngsters to make mistakes. Indeed many teachers see these mistakes as a key component of the learning process. Such teachers avoid setting up situations where the student is led to the 'right answer' which, having been arrived at with few demands being made of the learner in engaging with the problem, may then be rapidly forgotten. Thus mistakes are seen as a means of confronting students with the results of their theories and actions, of evaluating what has been done and of seeking a better means of achieving optimum results.

'Science for citizenship' is widely recognised as a central aim of science education. Thus a supple-

mentary question to that above as to the contribution of science to general education is: What do we want from the citizens of a technological society? One answer is that members of such a society should be willing and competent to act to improve the quality of life for themselves and others; to take responsibility. A central purpose of school learning then must be to increase youngsters' competence in taking responsibility, not least for their own learning. *The use of knowledge and understanding, and in seeing its relevance, is vitally important. Gaining some understanding of science without being able to apply it, or even see how it might be applied, seems a thankless task.* Thus science makes a contribution to the overall purpose of education by enabling youngsters to develop a sense of competence in dealing with and understanding the world in which they live, whether that world be a natural, a technological or a social one.

How can the purposes of school science be translated into an effective model for classroom teaching?

Figure 1 attempts to illustrate an interactive curriculum model within which youngsters can become self-directive learners who take responsibility for their own actions. The model may be either teacher- or student-directed, according to needs and circumstances. Hence the students work in cooperation with teachers in selecting approaches to learning that best meet their needs. The overall aim is one of helping youngsters to develop competence in using their science knowledge by sharing responsibility whenever this is deemed to be feasible and appropriate.

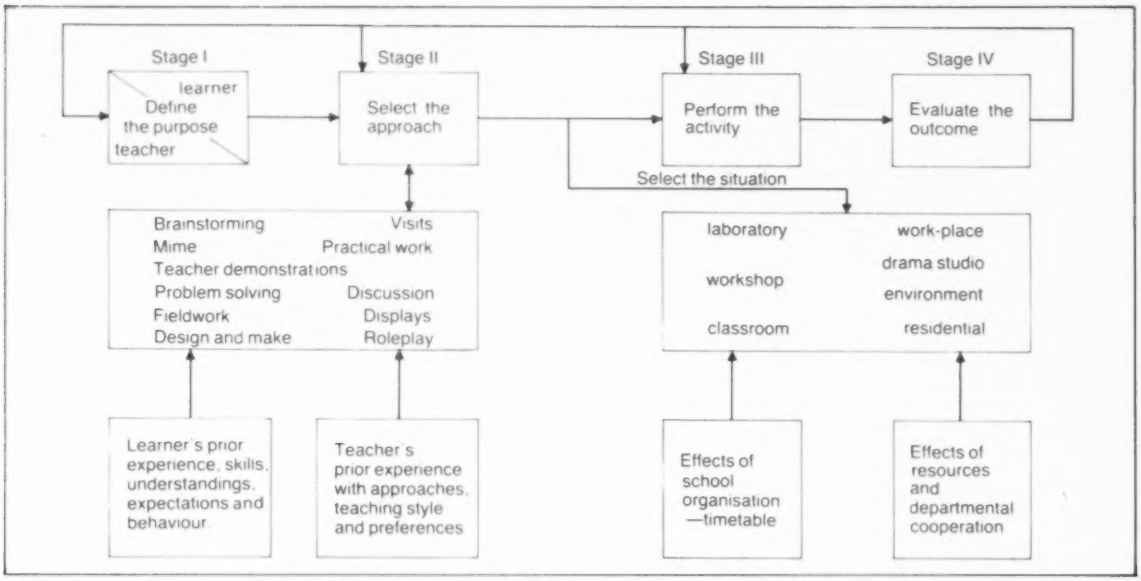


Fig. 1 *The interactive curriculum model*

The model suggests that effective teaching can best be thought of as a cyclic process. Four stages to this process are identified in Fig. 1 which are described here briefly and exemplified in Section 2.

Stage I: defining the purpose

This is an activity which ideally would be shared by students and teachers. It is appreciated that sharing such a discussion may depend upon the age, ability and motivation of the youngsters and of the teacher concerned. The agreed purposes may be designed for an individual lesson, a module of a science course, or the whole curriculum for one academic year.

Stage II: selecting the approach

To achieve the purposes requires planning various teaching approaches and learning activities appropriate to agreed learning objectives/opportunities. The learning activities can be approached and organised in a multitude of ways and the purpose of this Curriculum Guide is to show examples of different approaches. For an approach to captivate the imagination of students so that they learn actively it must be set in a *situation* which the pupils see as relevant – with outcomes which are recognised as of relevance to both the student(s) and the teacher. There are, of course, constraints operating in any school or

classroom, and these affect the feasibility of the approach. Such constraints might be, for example, the organisation of the timetable, staffing in the school, or the availability of resources such as transport for outside activities. A consideration of cross-curricular links is important and many of the approaches that are suggested here for science are also relevant to other school subjects.

It is recognised that the organisational structures within a school are to some extent a reflection of the approach to learning within that institution and the constraints imposed by certain structures can make it difficult to use certain approaches effectively.

Resources of time, space and personal investment are also dependent to some extent on the way in which the learning situation is perceived and the roles taken by pupil and teacher.

Stage III: performing the activity

This is the outcome resulting from Stages I and II, the purposes and learning approaches which have been agreed upon following discussions between student and teacher. Stage III describes what youngsters actually do in the learning situation.

Stage IV: evaluating the outcome

A continuous process of revision or judgement on the actual outcomes of the activities is an essential part of an interactive curriculum. There will be certain opportunities for outcomes which teachers wish to achieve. The youngsters themselves will have their own, albeit inexperienced and/or unrealistic, purposes and desired outcomes. By negotiation, some of these purposes will be agreed. At the end of the process, youngsters and teachers may (or may not) have achieved their expected outcomes. Equally so it is quite likely that for both of them other often unexpected outcomes will also have been achieved. Thus evaluation can be used to select subsequent purposes and activities. It may be that some groups achieve few of the anticipated purposes, which could then mean a repetition of work already covered. On the other hand, teachers may decide that purposes left unachieved simply need to be picked up in the next set of work. No longer ought there to be the notion of rushing through the work because it is there and has to be finished. It is important that approaches to learning should be sought which do result in youngsters achieving recognisable competences and that activities are open to change through discussion between the student(s) and teacher in order better to achieve these competences.

We will return to this sequence of Stages I – IV in the next section, where we explore further the whole process of selection of the appropriate approach(es).

SECTION TWO

Selecting an approach

Introduction

The purpose of this section is to enable readers to improve their selection of approaches to learning which meet the aims of the SSCR (**2.1**) or LEA/departmental/personal aims and purposes. In this section we revisit the interactive curriculum model (Fig. 1) and describe how it might operate within a fairly standard science lesson. We include an example of how the selection of an approach might become a shared activity between student and teacher.

How can approaches be selected to implement the interactive curriculum model?

The example of a unit on evaporation is used here to show how an approach might be selected and evaluated.

Stage I: defining the purpose

First the *purposes* for teaching evaporation need to be made explicit. It may be that the main purpose is for youngsters to gain patterns of knowledge, such as:

- rate of evaporation depends on area;
- rate of evaporation depends on temperature;
- rate of evaporation depends on wind speed;
- rate of evaporation depends on the material from which the evaporation occurs;

and/or it may be that this activity could be used to enable the youngsters to become competent in practical skills such as:

- measuring;
- experimental design;
- observing.

Alternatively the purpose could be suggested by the student as a result of personal interest or to develop previous activities.

Stage II: selecting the approach

If the sole purpose lies in the gain of factual knowledge, what would be the most efficient approach to use so that the knowledge could be recalled to mind? Would it be best for youngsters to perform a practical activity, observe a teacher demonstration, or complete a worksheet? Could one draw upon everyday experiences and institute structured discussion?

Science is, of course, not only about gaining factual knowledge and concepts. It may also be about the development of practical skills, solving problems, developing competence in the use of scientific ideas, interpreting the implications of science and technology for individual people, for industrial concerns, for the environment, for society, and so on.

Practical experiences will help youngsters to develop skills, but we need to have a clear view of exactly what practical skills are being developed. We need to consider whether the approaches and learning experiences we provide may achieve all the purposes we have in mind. More importantly, we need to ensure that the youngsters know what these purposes are, i.e. what both we and they are trying to do.

For example, many practical activities provide youngsters with opportunities to practise the complex social skills of working in a group, or to develop information-handling skills, but often these opportunities are insufficiently exploited. Only if the purposes of a lesson are perceived by the students as being relevant to their needs can we be confident that such learning opportunities may be taken by the students. It is certainly true that in many science lessons today youngsters are not aware of the many possible purposes the teacher is trying to achieve. Maybe we should share our purposes with the students and explore the possible variety of learning approaches available to us.

Stage III: performing the activity

So, how could a topic like evaporation be taught to help to achieve purposes other than gaining knowledge and practising skills? Consider the first lesson of such a unit of work, set out briefly in Box 2:

The introduction – brainstorming. Youngsters begin by writing down their ideas about evaporation and/or aspects of evaporation of which they have little understanding and wish to know more. This leads to the drawing up of group 'product' sheets listing their ideas. The purpose of this approach is to identify what the youngsters already 'know' and believe about evaporation.

This is followed by a class discussion which considers the ideas produced by the groups. Ideas are sifted into a set of action plans – things youngsters need to do in order to investigate their ideas. These may include practical investigations, or information-handling exercises, for example.

Subsequent lessons might continue with a whole range of activities decided upon by the youngsters themselves, such as group, class or individual practical investigations, problem solving activities or library visits.

***Box 2** A first lesson*

This example gives some idea of how different approaches can begin to enable youngsters to have a much firmer commitment to their own learning activities, and begin to achieve the full range of aims discussed above.

Stage IV: evaluating the outcome

At the end of all these activities, both teacher and student will want to know if they have achieved their purpose. Both will need to evaluate the outcomes of the activity. The actions to be taken in evaluating the outcome of the activity are described on the flowchart in Fig. 2.

How can learning approaches best be selected in order to meet specific aims and purposes?

Having looked at the whole learning process as demonstrated by our interactive curriculum model, we can now begin to focus on the selection of an approach which would be appropriate for a specific purpose. Figure 3 gives an example of a possible guide or check grid to choosing an approach. Here the selection is made by means of a grid in which the desired learning outcomes incorporated in the aims of the SSCR (**2.1**) are set against a range of elements involved in the learning process. Readers may have a different set of aims from the particular listing given, but this does not invalidate the instrument. Science departments are encouraged to produce their own variables to set on the axes. For any coordinated point within the grid, the teaching/learning approaches which may be appropriate can then be listed and selected.

Which learning outcomes?

There are many possibilities for choice here. Sources such as the APU, the Department of Education and Science (DES) in its recent statement *Science Education 5–16: A statement of policy* (**2.2**), and the SSCR itself, through publications such as *Towards the Specification of Minimum Entitlement: Brenda and friends* (**2.3**) have all made statements about the desirable learning outcomes of science lessons. The real need is for teachers to

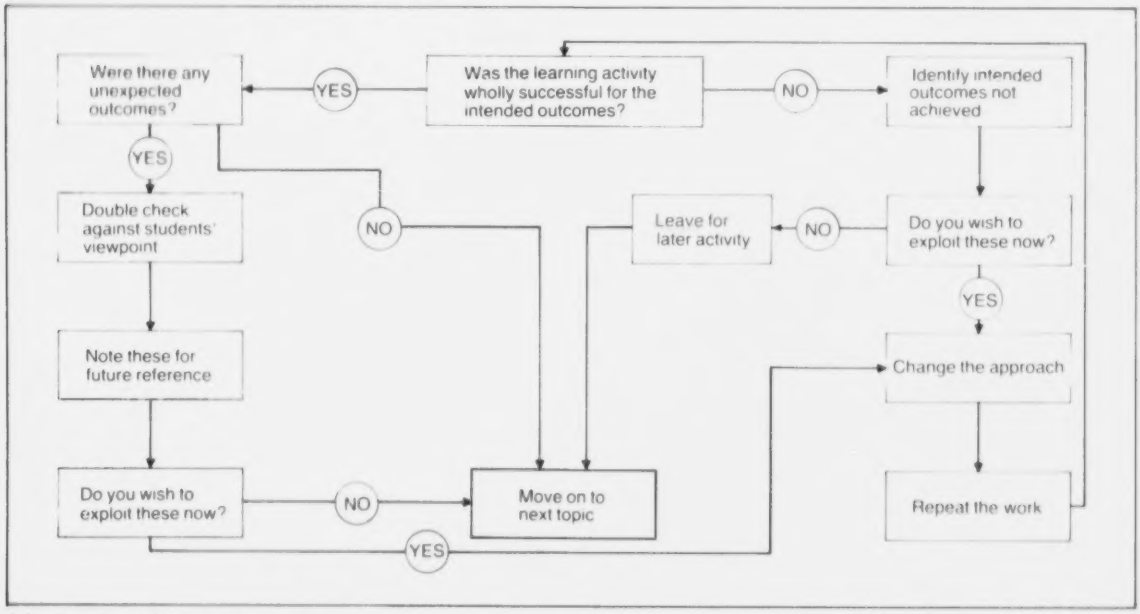


***Fig. 2** Stage IV: evaluating the outcomes*

identify required learning opportunities, and judiciously select appropriate approaches to teaching and learning.

One prime learning objective, which all teaching approaches should ultimately be striving to achieve, is the notion of competence (See **Better Science: Choosing content**). Competence has been defined by the SSCR as being the ability to *use* knowledge, understanding, process and practical skills, in order to act effectively to achieve defined purposes both both within an immediate context and across appropriate contexts. Elements of the grid (Fig. 3) are necessarily composed of smaller and less all-encompassing objectives than this. It is, however, this goal which we are ultimately pursuing.

Using the instrument: an example

To exemplify the use of the instrument, an example is given of a grid (Fig. 3) with a set of learning opportunities which range from observing to a number of 'own variables' that would be specified by a science department. In this particular case, these represent a set of scientific skills. Two of the cells in the matrix have been identified (A and B), by drawing upon the set of teaching approaches given above and attempting to answer the question:

- which activities would best enable us to provide this learning opportunity?

This implies some notion of comparison, because it may be that other approaches might be useful, but each of us might have different criteria as to why some activities might be more effective than others. Criteria for evaluating how effective an approach might be are discussed in Section 4 and in Fig. 2. Evaluation is an important part of the selection process for future activities.

Aims of the SSCR	Observing	Measuring	Recording	Manipulating	Designing	Questioning	Searching	Listening	Own variable	Own variable	Own variable	Learning opportunities
(a i) explore the nature of the biological and physical environment through observation, experiment and systematic enquiry;												
(a ii) develop the ability to design and carry out experiments, evaluate evidence and solve problems;	A											
(a iii) study the key concepts and principles of science that are essential to an understanding of science as a way of looking at the world;												
(b i) use their knowledge of science to design and develop solutions to technological problems, to test and evaluate those solutions and to cost such exercises;										? C ?		
(b ii) study the key areas of science and technology that relate to the world of work and leisure so that they are better able to participate in a democratic society;												
(b iii) study key concepts that are essential to an understanding of the part science and technology play in a post-industrial and technological society;												
(c i) gain some understanding of the historical development and contemporary cultural significance of scientific principles and theories;								B				
(c ii) appreciate that technologies are expressions of the desire to understand and control the environment and that technologies change in response to changing social needs;												
(c iii) appreciate that past scientific explanations were valid in their time and that early technologies are still valid in some cultural contexts;												
(d i) study those aspects of science that are essential to an understanding of oneself, and of one's personal well-being;												
(d ii) discuss, reflect upon and evaluate their own personal understanding of key scientific concepts, theories and generalisations;					? D ?							
(d iii) explore topics or themes which exemplify the limitations of scientific knowledge as an explanation of the human condition.												

Fig. 3 An instrument for selecting learning approaches

The case of cell A. Which approaches would best develop the skills of observing, in designing and carrying out experiments, evaluating evidence and solving problems?

We cannot make any absolute statement concerning the matching of teaching approaches to learning outcomes. We can draw upon teachers' experience, professional expertise and intuition to select approaches which we think might work. That being said, we suggest that fieldwork, computer-aided learning, visits, practical work and discussion are most likely to fulfil the aims A above. The skills of observation would be enhanced by the discussion of what had been observed, and the practise of such skills would be best achieved by creating situations for youngsters in which observation was a featured process.

The case of cell B. Developing listening skills through some understanding of the historical development of science

It is suggested that these skills might best be developed in this context by using comprehension, drama, interviewing, information-seeking and role-play techniques. The skills of listening involve personal activities which go hand in hand with questioning and seeking, and thus activities which engage with others might be the best ways of exploring such skills.

Boxes C and D on the grid would be met by different clusters of approaches and readers may wish to debate what these might be. Clearly, in order to do this, they will need to specify their own variables for cell C.

SECTION THREE

The 'ideas bank' of exemplars

Introduction

This section forms the main body of the Curriculum Guide. The exemplars were selected by a team of experienced teachers to illustrate many different learning approaches. The case studies which follow were prepared during two four-day residential writing conferences and draw on the collective expertise of members of the writing team. The section includes:

- a glossary of some of the terms used;
- a description of how the exemplars are set out;
- the exemplars themselves.

What is meant by 'approaches'?

The term 'approaches' is used here to represent the methods used by teachers to engage learners with tasks designed to bring about meaningful learning and provide particular kinds of learning opportunities. Ideally, individuals or groups of students might discuss particular purposes and select approaches with the teacher as their guide. This should capture the imagination and interest of learners in purposeful activity and so further students' knowledge, understanding or skills.

The approaches adopted by a teacher may be in response to events within a lesson which were perhaps unanticipated, but which create special learning opportunities which should be pursued. Thus the term approaches does not imply a mechanistic style of teaching where the teacher is armed with a range of techniques to be deployed as appropriate, with students who do not participate actively in the the learning process.

Which approaches do we refer to?

The approaches described in this document are listed in alphabetical order, beginning with Brainstorming in the glossary below. Definitions are given in a brief 'sketch' as to what we mean by each approach, and are not intended to create hard and fast rules but rather to enable understanding. The glossary, which is by no means exhaustive, includes well-tried approaches and others which will be less familiar. The non-inclusion of an approach, e.g. lecturing, does not suggest that it is of no value, but simply that it does not feature in any of the case study exemplars which follow.

BRAINSTORMING: an activity taking place in small groups (optimum, say, six) in which all group members call out wide-ranging and associated ideas on a topic in question for a short pre-specified time (commonly five minutes). One person writes down each suggestion. Repetition is allowed but clarification and discussion are not. Discussion and synthesis of the ideas produced are an essential follow-on activity and are not really part of the 'brainstorm' itself. Variations do allow for bigger groups (maybe a whole teaching group) and for longer time (perhaps 10 minutes) (**3.1**).

COMPREHENSION: activities in which youngsters, individually or in groups, explain what they understand from pieces of text – for example scientific writing, experimental descriptions, practical instructions. The activities may be ones which involve text-handling, reading, listening, ordering of data and so on.

COMPUTER-ASSISTED TECHNIQUES: involve the use of computers to simulate situations which change as the user operates on them when investigating possible solutions to problems. Computers can be used to hold data in such a form that it can be reorganised (graphs, spreadsheets, . . .) and can be interrogated rapidly in a variety of sophisticated ways (**3.2–3.4**).

DART: an acronym for Directed Activities Related to Text. DARTs provide ways of actively engaging pupils in reading and analysing text. Text here refers to any extract of written material (or spoken by being read aloud) which can stand on its own as a unit of learning. The activity gives the students a clear sense of the purpose of reading and may involve students in asking questions about what they need to know. It can also involve the generation and testing of hypotheses by students which they can check against the text, and then discuss with other students (**3.5, 3.6**).

DEBATING: is based on a formal presentation of a prepared argument and counter-argument.

DISCUSSION: exchange, explanation, analysis and synthesis of ideas between two or more individuals. Activities involve periods of explanation, clarification, questioning, listening, exploration, analysis and synthesis and require adequate time for each of these stages to occur.

Ideally, all group members should be fully engaged throughout. In **peer-led discussion** the group nominate a leader who is then responsible for ensuring that that discussion follows through the various stages identified above or others specified by the teacher (**3.7–3.10**).

DRAMA: activities which enable youngsters to see the processes and consequences of a series of actions forming the drama, as they are acted out in front of them. There is direct involvement by a minority of the group as actors in roles in the drama, but the majority of youngsters respond to the drama they watch, and weigh up its implications and consequences. **Mime** is a form of drama enacted without the use of speech (**3.11**).

FIELDWORK: a series of activities which take place outside the school and which contextualise science in situations other than the laboratory. The activities may involve observation, data, collection, identification, analysis, hypothesising, and other areas of practical skills. Fieldwork may be followed by a period of classroom or laboratory investigations on the data collected and the observations recalled, ordered and reviewed (**3.2–3.4**).

INFORMATION SEEKING: an activity which involves questioning data bases which could be in the form of people, books, computer files, journals, newspapers, archives, etc.

INTERVIEWING: questioning others to probe their views and opinions upon particular topics. This can be done in groups, or on a one-to-one basis, aided by tape recording or video. It may involve the construction of a list of questions before the event, or be a more open-ended and spontaneous investigation. The analysis of the data is always interesting and problematic.

PRACTICAL WORK: aspects of science which involve setting up problems and seeking solutions. They may or may not involve apparatus and manipulative skills. They almost certainly involve aspects of 'hands on' experimentation and investigation. In science terms experimentation refers to the testing of a hypothesis and is thus only one aspect of practical work, which is considered to be the whole process of design, performing experiment(s) and reporting and evaluating experimental results (**3.12**, **3.13**).

PROBLEM SOLVING: a problem is a question, a matter for concern, which has the distinct characteristic that it has a number of solutions. Technological problems are those which relate to human need. Problem solving is the process using analysis, judgement and evaluation based upon experience, knowledge and inventiveness in order to find the optimum solution to a problem (**3.14–3.17**).

REPORTING: conveying to others the results of an activity. The report may be written, visual, oral, non-verbal (as in the case of mime or movement). Thus reporting could take the form of laboratory notes, diaries, creative writing, tape recordings, video film, wall displays, or an oral report. Whatever the case, it concerns preparing materials according to the needs of the 'audience' and conveying understanding of the topic in question.

ROLE PLAY: enacting, by individuals or groups, some aspects of another person's life. Role play may be devised by youngsters themselves, it may or may not be scripted, may use observers as well as players, and may involve any number of people. Its main objectives are to allow youngsters to gain access to the experiences and feelings of others in particular situations. Unlike drama, any observers are not just passive participants, but are allocated specific tasks feeding into the process at the stage of analysis of experiences and other relevant objectives (**3.18**).

SIMULATIONS: reconstruction of aspects of reality in the classroom so as to create situations that youngsters might meet in the future, or may already have experienced. They may involve the use of a computer and draw on problem-solving skills. This can lead to attempts to enable youngsters to 'act out' sets of possible solutions to situations and to assess them critically (**3.19**, **3.20**).

VISITS: an outside activity to allow observation, exploration and questioning by youngsters of aspects of science and technology outside the school laboratories, e.g. trips to industrial organisations, museums, and other places of interest. They may also involve outsiders visiting the school so that youngsters can explore their perceptions of particular aspects of science.

The layout of the exemplars

The exemplars in the next pages follow a similar format throughout. Each one focuses on a particular theme and is based upon original work submitted by teachers. The original case studies have been supplemented and developed to provide a series of commentary notes and suggested alternative approaches to what might initially have taken place.

Each exemplar is detailed in a four-page spread. The first page provides a summary of purposes – the aims and objectives for what is taking place – along with a synopsis of events. The second and third pages, the centre-spread of the exemplar, work in two ways. On the second page the sequence of events is shown with some indication of the time-scale involved. These are called 'ways in' to the theme and the approaches being used,

and the sequence is shown by vertical arrows down through the boxes. On the third page each particular approach is highlighted in greater detail with notes and commentary on how it was used, the pitfalls encountered, and the outcomes that might be expected. Further over on this page some alternative approaches are provided so that different teachers can take different tacks in different situations or contexts. This gradation of detail, drawn from the original case study, is shown by horizontal arrows (left to right) across the double spread of the second and third pages. The fourth page contains references (in particular to the work of other teachers and SSCR working groups who have attempted such exercises), a bibliography and any further notes and commentary that might help. This layout is represented in Fig. 4.

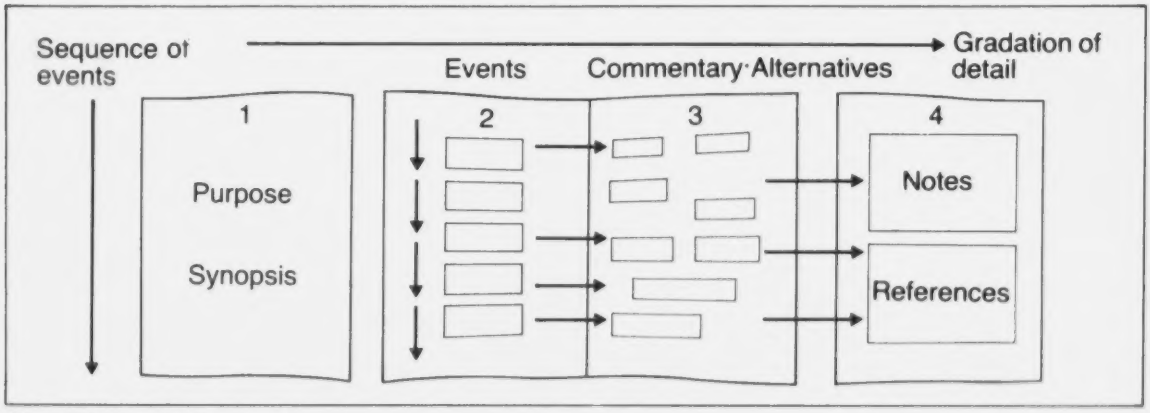


Fig. 4 Layout of the exemplars

SCIENCE THROUGH HEALTH EDUCATION

PURPOSE

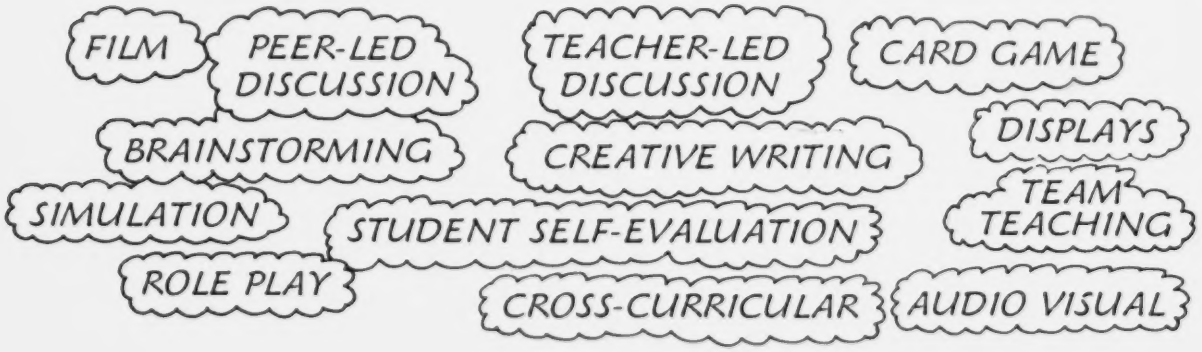
This exemplar endeavours to promote the development of an enquiring mind and decision-making skills relevant to everyday life. It concentrates on *three* crucial issues – **alcohol**, **tobacco** and **sex relationships**.

SYNOPSIS

The case study which follows describes a scheme of work designed for mixed ability and coeducational groups in the Upper Secondary School. A wide range of **approaches** are used in order to facilitate the learning process. Knowledge by itself is not enough when exploring the implications for individuals and society. Characteristics encouraged by this work include the ability to listen to the views of others, to keep an open mind, and through an exploration of the scientific evidence to provide opportunities for students to change their views without any loss of face. It is recognised by the teacher that information is important, since with some understanding of the appropriate body systems students can make a more worthwhile choice about both their health and behaviour. For example when students realise that ova are not always released regularly and can live for 1 – 2 days, that the male releases on average about 300 000 000 sperm, some surviving for several days, they begin to see more significance in the personal choices they can make. Here various **approaches** help in preparing for these choices. In this kind of education and outcomes last for a lifetime.

The teachers provide a flexible working environment both for each lesson and from week to week. They move from **LARGE GROUPS** in **TEAM TEACHING APPROACHES** to **SMALL CLASS GROUPS**, subdivided further for **PEER-LED BRAINSTORMING** and **DISCUSSION** – to be reconvened as a whole group for the sharing of collective experience and conclusions.

All of this work builds upon foundations laid down in the primary school and in lower school Science and there are constant and continuing **CROSS-CURRICULAR LINKS** with English, Home Economics, Physical Education and Religious Studies. The latter subject is seen as a vital part of students' social and moral development.



WAY IN

LESSON ON ALCOHOL LASTING 1 HOUR 15 MINS.
Half the year group watch a film introducing facts relating to the action of alcohol upon the body and see some consequences relating to teenage parties and driving. There are three choices of follow up activities:

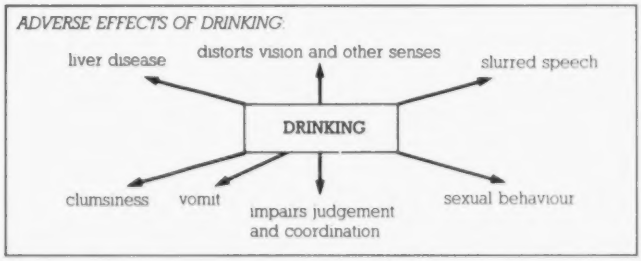
CHOICES

CHOICE OF FOLLOW UP WORK

A. Class groups divide into groups of 2–3 and **DISCUSS** the behaviour they have seen and suggest alternatives. The whole class then considers the conclusions of the various groups.

B. Class divides in half and plays 'the Alcohol **CARD GAME**' by TACADE which covers the facts about alcohol whilst allowing the students to interact with each other.

C. The half year subdivides into groups of 6 for **PEER GROUP-LED BRAINSTORMING** and **DISCUSSION**:



Students then **REPORT FINDINGS** to whole group.

FOR ALL

LESSON ON SMOKING LASTING 1 HOUR 15 MINS
A **TEAM TEACHING** approach enables a half year group to come together for a **FILM** showing the effects of smoking on various body systems. Teachers then take own groups for **CLASS** and **SMALL GROUP DISCUSSION** relating to *why* people smoke, consequences of passive smoking and implications for public places.

Follow up work includes **CROSS-CURRICULAR ACTIVITIES** on controversial issues in English **FOLIO WORK**, **VISUAL DISPLAYS** and **SCHOOL ASSEMBLIES**. Students complete an **EVALUATION SHEET**.

UNIT ON SEX EDUCATION/RELATIONSHIPS: 4 × 1 HOUR 15 MINS.
The unit is about marriage, child care and family life. Factual information relates to conception, pregnancy, birth, contraception and abortion. Parallel to this pupils begin to understand something of the cognitive, emotional and physical development of the child. Pupils experience a variety of approaches, e.g. **SIMULATION**, **ROLE PLAY**, **AUDIO VISUAL**, **TEACHER** and **PEER-LED DISCUSSION**.

COMMENTARY	ALTERNATIVE APPROACHES
FILM provides a useful way of presenting facts to mixed ability groups. It is also a means of introducing a topic, enabling students and teachers to identify prior knowledge and set realistic 'starting points' for building further skills and ideas.	**Textbooks** that are well illustrated help **PERSONAL RESEARCH** both in school and at home. Others use classroom diagrams, displays and students to report to and teach others.
PEER-LED DISCUSSION enables students to discuss issues in a non-threatening way in preparation to feeding into the whole class. Students use the session to relate facts to everyday life and benefit from each others' experience.	**TEACHER-LED DISCUSSION** ensures that issues are presented step by step so that students can develop this technique, e.g. jot down three reasons why smoking in a public place is undesirable for some. Students then report back or share ideas with those next to them. **HOMEWORK** follow up by **INTERVIEWS** of attitudes of parents neighbours, etc.
The **CARD GAME** is a means of presenting facts such as comparative strengths and units of alcohol, the time it takes for the body to process alcohol, licensing laws and so on.	**BUZZ SESSION** could be used to recall facts quickly – ask pupils to think of three answers in brief 'thinking time' before you begin. Use a **CLASS QUIZ**, or students may devise their own game in small groups. **CARD GAMES** have been used for genetics and nutrition education.
In **PEER GROUP-LED BRAINSTORMING** a member of the group records ideas onto a prepared pro forma ready for feedback into the whole group. Thus students formulate ideas on one issue in preparation to listening to the views of others. In this instance, each group contributes about eight suggestions, as many as 30–40 being gathered collectively.	Teacher may hand out **INDIVIDUAL WORKSHEETS** and students confer with each other on completion. Ideas can then be **DISPLAYED** on blackboard or overhead projector. The class can prepare a **'CASE HISTORY'** of a real life situation where a decision has to be made, e.g. whether to accept a drink in a pub at sixteen. A **STORY** for a **SCHOOL MAGAZINE** on some controversial issue is encouraged in some schools.
SMALL PEER-LED DISCUSSION is a natural part of the **BRAINSTORM** on 'saying no' to accepting another drink, and students begin to show some evidence that to say 'no' is not 'chicken'.	**TEACHER-DIRECTED DISCUSSION**, with the leading role being taken by the teacher instead of the students.
TEAM TEACHING can enable teachers to enrich their own knowledge and experience by working collectively. Follow up work from **Free to Choose** and **Health Education 13–18** is carefully chosen and pinpoints key issues, providing pupils with structure for their activities.	A **GUEST SPEAKER** is sometimes used to introduce a topic on a new or controversial issue. It is, however, most important that s/he is briefed well as to what has gone before and the nature of expected outcomes.
CROSS-CURRICULAR activities can follow such as when students prepare **VISUAL DISPLAYS** to discourage smoking and use these lessons as a stimulus for their **FOLIO WORK** in English.	One school developed **LINKS WITH SEVERAL DEPARTMENTS** in order to promote a no smoking school. Personal and social education is made more effective when key issues are related to Religious Education, Life Skills, Child Care, Home Economics, Art/Design, Science and so on.
STUDENT SELF-EVALUATION is a useful technique. Students are consumers and teachers find it helpful to know their views about topics and approaches. **STUDENT QUESTIONNAIRES** from **Health Education 13-18** are used.	Some schools **DESIGN THEIR OWN EVALUATION** based on interest and usefulness of topic. Others judge success/interest by attendance.
SIMULATION provides a useful way of enabling the class to experience many solutions to real life problems and evaluate the situation, developing new ways of looking at things. E.g. do you put stabilisers on a bike for a 3-year old? Many say 'Yes, because the child will fall'. An equal number say 'No, let the child learn by experience'. A few say, 'If the child is confident and has good balance, s/he probably doesn't need them'.	Simply **WRITING ABOUT ISSUES** is one way of exploring ideas after, say, reading case studies. Students may listen to a panel of 'experts' in e.g. child care or contraception. Sometimes a **TEAM OF TEACHERS** can put forward alternatives to stimulate ideas and modify attitudes.
This school tries to stress the sheer wonder of the process of creation, from conception to birth. **FILMS** and **TAPED INTERVIEWS** are seen as a stimulating way to help achieve an awareness of the responsibility of parental care. Followed by **ROLE PLAY**, **DISCUSSION** and contemplation of attitudes. Much follow up work is possible in Religious Education.	These methods are designed to increase knowledge and awareness. **Well illustrated books and posters** can do this. People with 'hands on' experience can help but caution is sometimes required in these three areas when using children for this task. This approach can over-stimulate and have the reverse effect.

COMMENT AND SUMMING UP

A general approach to these topics within the science curriculum tends to be one with great emphasis on information giving. This is an important aspect when considering the three topics mentioned but there is evidence that where this kind of education is related to real life issues students find more interest in learning, attend better and attain more personal benefit.

The series of approaches outlined on the second and third page of this case study are not time consuming and help the young people relate information to themselves and so begin to understand and make more reasoned decisions.

The **Think Well** series, **Health Education 13 – 18** and TACADE material are an invaluable support to this kind of approach.

Where students have experienced several such approaches, as in the **My Body** project trialled in a group of five primary schools in North Cumbria, they have gained knowledge by scientific practical experience. They have been involved in what the secondary school calls '**CROSS-CURRICULAR ACTIVITY**'. The purpose of this work is to promote more student autonomy and opportunities for growth in self-confidence. The students learn through sharing experiences with each other and the teacher. There is substantial student participation. This project allows for a variable approach, e.g. students **RESEARCH FACTS** – then feed back to others, **DEBATE** health issues and negotiate topics for further study. The students respond to being valued and teachers learn to give up some autonomy – not to be confused with authority. Students gain many skills such as listening and sharing ideas, and become more confident. They also learn much valuable information.

This project is about creating a learning environment supportive to the sharing of opinions and experiences and is about **process** as much as **content**.

Children throughout the country are experiencing this kind of learning in their primary school and their expectations of secondary science must surely be high. They have already used microscopes, examined a small skeleton and manipulated parts of the body on a torso as well as observing the dissection of heart and lungs.

The implications for science in the secondary school are numerous. There is certainly a need to discover the nature and extent of science covered in feeder schools – such diversity in itself is a challenge. Teachers should also consider the merits of **CROSS-CURRICULAR ACTIVITIES** and seek ways to provide experiences which are stimulating and informative, and so provide continuity – progressively deepening the existing understanding of young people.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by J.M. Barnfield and N. White of Thorncliffe School, Barrow in Furness, Cumbria.

Exemplar in 'Comment and Summing Up' supplied by Paul Hayton, Advisory Teacher, Ireby Church of England School, Cumbria.

Materials, audiovisual material, books, pamphlets, posters and workshops from:

Evans, M., Rice, B. and Gray, G. *'Alcohol, What Do You Know?'* card game from *'Free to Choose'*, TACADE, 1983

My Body, Health Education Council Project, Heinemann, 1983

Health Education 13 – 18, Schools Council/Health Education Council Project with the Scottish Health Education Group and the Transport and Road Research Laboratory, Forbes, 1982

Parents and Teenagers, Open University in association with the Health Education Council and the Scottish Health Education Group, Harper and Row, 1982

BBC Education materials with broadcast dates:

Science in Action (TV); *Keep it Clean*, Autumn 1986

Science in Action (TV); *Body Machine*, Spring 1987

Other educational broadcasting materials:

Yorkshire Television: *Scientific Eye* for 11 – 13 year-olds, *Microbeasts and Disease*.

Granada Television: *Your Living Body* for 14 – 16 year-olds, programmes such as *Skin Deep*.

Granada Television: *Facts of Life* feature aspects of sexual relationships.

Central Television: *Choices* for 11 – 13 year-olds feature such issues as drug use and abuse.

SCIENTISTS THINKING AND WORKING WITH AIR – A WHOLE-DAY APPROACH

PURPOSE

To emphasise the skills and processes of generating and developing scientific hypotheses on a familiar yet difficult set of scientific ideas about air. To foster cooperation between primary, middle and upper schools.

SYNOPSIS

The approach here is to use a whole day to generate and test ideas for some unexplained observations. The early part is used to provoke hypotheses which are then tested experimentally. It was used originally with mixed groups of primary school pupils and first-year secondary pupils, with their teachers, as an interesting form of primary–secondary liaison. The point is to **explain** some 'happenings' or problems. The topic here is about 'Air', though many other topics could be approached in the same way. The work has two strands: to emphasise the processes of hypothesis testing; and to explore the behaviour of air.

TEACHER DEMONSTRATIONS

TEAM TEACHING

LABORATORY-BASED INVESTIGATIONS

BRAINSTORMING

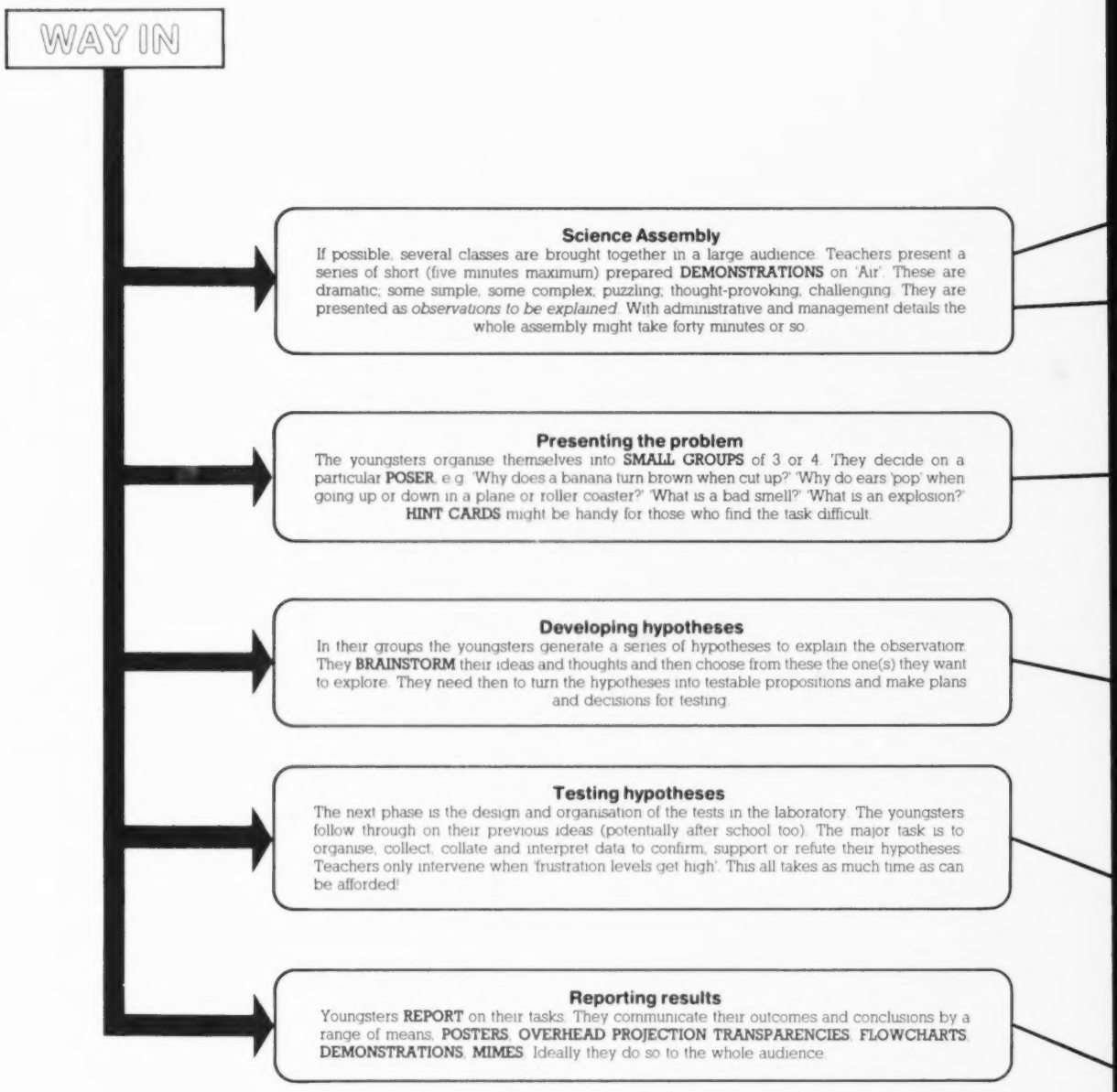
POSERS

SMALL GROUP WORK

STUDENT SELF-EVALUATION

REPORTING

HINT CARDS


WAY IN
Science Assembly
If possible, several classes are brought together in a large audience. Teachers present a series of short (five minutes maximum) prepared DEMONSTRATIONS on 'Air'. These are dramatic; some simple, some complex; puzzling; thought-provoking, challenging. They are presented as observations to be explained. With administrative and management details the whole assembly might take forty minutes or so.
Presenting the problem
The youngsters organise themselves into SMALL GROUPS of 3 or 4. They decide on a particular POSER, e.g. 'Why does a banana turn brown when cut up?' 'Why do ears 'pop' when going up or down in a plane or roller coaster?' 'What is a bad smell?' 'What is an explosion?' HINT CARDS might be handy for those who find the task difficult.
Developing hypotheses
In their groups the youngsters generate a series of hypotheses to explain the observation. They BRAINSTORM their ideas and thoughts and then choose from these the one(s) they want to explore. They need then to turn the hypotheses into testable propositions and make plans and decisions for testing.
Testing hypotheses
The next phase is the design and organisation of the tests in the laboratory. The youngsters follow through on their previous ideas (potentially after school too). The major task is to organise, collect, collate and interpret data to confirm, support or refute their hypotheses. Teachers only intervene when 'frustration levels get high'. This all takes as much time as can be afforded!
Reporting results
Youngsters REPORT on their tasks. They communicate their outcomes and conclusions by a range of means, POSTERS, OVERHEAD PROJECTION TRANSPARENCIES, FLOWCHARTS, DEMONSTRATIONS, MIMES. Ideally they do so to the whole audience.

24

COMMENTARY	ALTERNATIVE APPROACHES
Short, exciting **DEMONSTRATIONS** are a powerful way of engaging interest, provoking ideas and posing problems. Historically this was the main approach! It is particularly good where the demonstration is left without resolution (no answers given). It is a chance to be showman/presenter/impresario.	The audience does not have to be several classes. It might just be one class, with one or two teachers working together. The time might be used over several weeks rather than one whole day. The initial stimulus might be different – a **VIDEO** of a **DRAMATIC EVENT**, a major **NEWS ITEM**, a **LOCAL OCCURRENCE**
TEAM TEACHING to present a series of snappy (convincing) **DEMONSTRATIONS**, on cue, with impact requires team effort, coordination and organisation. It allows each teacher to make his/her own presentation 'in concert' with others.	
Working in **SMALL GROUPS** develops decision-making skills, communication skills and skills of negotiation. This phase of organisation can be pre-set (groups already organised) or students can be left to group themselves. They need to keep track of their decisions so that they can revisit them later (choose a scribe; use a tape recorder). The purpose is to settle on a particular issue that excites them. It needs to become **their own problem** – even if stimulated by an external set of observations. This phase might take twenty minutes.	The class might set up a **SIMULATION** as a **GROUP OF CONSULTANTS** who are asked to explore a particular issue. For instance, a local farmer might send samples of soil from two fields and want advice on the one best for growing wheat. Groups would need to generate hypotheses about conditions important for soil so that wheat grows well.
The hypotheses to explain the observations are generated by **BRAINSTORMING** – a fast flow of thoughts and ideas. These are then shaped into testable propositions. There are some 'rules' to brainstorming that need to be observed: • taking turns (or making sure everyone makes an input); • no discussion or shouting down ('till later?), every idea is included at this stage; • no limits to ideas, everything counts, but a strict time limit. Allow five minutes for a true brainstorm session, although variations of this approach can take longer.	The difficult stages to manage are those of turning the hypotheses into testable propositions, and then shaping the tests so that they come within 'available resources'. It might help to spend time before the day trying to predict the sort of directions the youngsters will choose so that resources can be anticipated. It might mean that previous lessons have to be used to explore what 'testable' means, what a 'fair test' is, what 'evidence' means, and what kind of evidence can be used to confirm or refute an hypothesis.
At this stage the students embark upon **PRACTICAL WORK**. Tests are designed, equipment and organisation planned, variables controlled, tasks apportioned, hypotheses pursued, data recorded and processed. The most difficult process is **negotiation**: negotiating within the group quite which (and how) hypotheses are testable, who does what, and negotiating with 'resource-providers' the limits to the scale of the operation. Youngsters might use a pro forma which outlines their expectations. This takes up the bulk of the day's work.	
Youngsters **REPORT** back their hypotheses, designs, explorations and outcomes to the others. They might all return to **PRESENT THEM TO THE FULL AUDIENCE**, or **WRITE REPORTS** for a later day. They might want to report their perceptions of the day – its value as a science activity and their effectiveness in tackling the issues involved.	In one school a similar one-day approach was used, where the youngsters were given a choice of prepared **POSERS**. They assembled in the gymnasium and had the whole day to prepare and test their ideas. They **REPORTED BACK** at the end of the day and completed **SELF-EVALUATION QUESTIONNAIRES**. (Dave Wallwork, Ailwyn Community School, Cambridgeshire)

COMMENT AND SUMMING UP

Generating and testing hypotheses are processes that occur in many circumstances within science. Some would argue that it is at the very heart of science. This exemplar explores hypothesis testing as either a central scientific process or as a way of approaching a particular topic on, say, air or disease. The hypotheses are stimulated by a dramatic input – either by **'QUICK-FIRE' DEMONSTRATIONS** or **VIDEO**. In either case the observations need to be explained.

SMALL GROUP WORK, whether **BRAINSTORMING**, making decisions or generally **DISCUSSING** options, is an invaluable approach in science. Students often find it less threatening than whole class work , and then might feel able to suggest the more 'outlandish', unexpected, creative or tentative hypothesis; in small group work the number of hypotheses or decisions to make can be more easily contained and sharpened and the difficult task of turning a hypothesis into a testable proposition is manageable. It also provides an opportunity to enhance many general communication skills such as listening, through approaches such as **CREATIVE WRITING**, **NOTE TAKING**, **REPORTING**.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar evidence supplied by Dr J.D. Buchanan, Ms C. Yates, Mr N. Ibberson formerly of Greenhill Upper School, Rochdale with the support and assistance of Mr D. Edge, Science Adviser.

Some examples of problem-solving activities can be found in the booklet by A. Howlett (SSCR Cambridge Problem Solving Group) *Problem Solving and the Art of Teacher Maintenance*; *Problem Solving in School Science: Does it Work?* Videos from the Ely Resource Centre, Cambridgeshire, and *Doing Problem Solving: A Collection of Ideas and Approaches* (eds Heaney, J.C. and Watts, D.M.) SSCR, in press.

For examples of some demonstrations/discussions see:

Minstrell, J. Explaining the 'at rest' condition of an object. *Physics Teaching*, January 1982.

Freyburg, P. and Osborne, R. *Learning in Science*. Heinemann, 1985.

An example of brainstorming is given in:

Nussbaum, J. and Novick, S. Brainstorming in the classroom to invent a model: a case study. *School Science Review* **62**, 771 – 778, 1981.

Some examples of the hypotheses youngsters develop are explored in: Driver, R., Guesne, E. and Tiberghien, A. *Children's Ideas in Science*. Open University Press, 1985.

BBC Education materials with broadcast dates

Investigating Science (TV), *Strange People in White Coats*. Summer 1987.

Investigating Science (TV), *I Wonder Why*. Spring 1987.

Other educational broadcasting materials

Yorkshire Television. *Scientific Eye, Lighter than Air*.

SALT ACROSS THE WORLD – MULTICULTURAL EXPERIENCES THROUGH SCIENCE

PURPOSE

To show how to adopt a multicultural approach for the study of **salt**, a traditional area of the science curriculum. Furthermore there is an exploration of the importance and value of different **scientific and technological processes** designed to meet differing **social and cultural needs** within available resources.

SYNOPSIS

This exemplar provides a fresh approach to teaching a traditional science topic. Some of the SSCR aims are embedded in the lesson and pupils are involved in exploring the nature of the physical and biological environment through observation and in **DESIGNING AND PERFORMING AN EXPERIMENT** to **SOLVE A PROBLEM** posed by the teacher. The processes and skills of science are common to all regardless of age, sex, culture or social class. This is recognised by the teacher in this lesson which has been trialled in an inner city school with students from a broad range of social and cultural backgrounds. Science teachers not in multicultural schools may wish to incorporate science and technology from other countries into their curriculum and use this exemplar as a model. A range of learning and teaching approaches, which are cheap to implement, are used. The teacher uses these (a) to establish existing student knowledge, and (b) to provide an enjoyable and varied range of student activities.

BRAINSTORMING

SMALL GROUP DISCUSSION

LISTENING

COMPREHENSION using DARTS

CLASS DISCUSSION

HINT CARDS

WORKSHEETS

WALL DISPLAYS

BRAINSTORMING

VIDEO

TAPE RECORDED SIMULATED REPORTS

PROBLEM SOLVING

MIME

EXPERIMENTS

CROSS-CURRICULAR

INFORMATION SEARCH

WAY IN

The teacher introduces the lesson by a **BRAINSTORMING** session, asking each child in turn this question, 'What comes into your head when you hear the word SALT?'

(5 min)

The class is then divided into **SMALL GROUPS** (minimum size 2) and asked to prepare a **MIME** on a way of using salt. Students discuss their ideas and plan their mime. The teacher has some **HINT CARDS** for those groups which cannot generate their own ideas, e.g.

1. Salt improves the flavour of food and is used world wide in cooking. It is used in breadmaking to help yeast work.

2. A teenager in Tanzania needs 6 grams of salt per day. A teenager in Russia needs 3 grams of salt per day. It is vital for blood, kidneys and stomach, without it they would stop working properly and we would eventually die.

(5 min)

The teacher asks each group in turn to perform their **MIME** for the rest of the class. Observers have to try to guess the use of salt in each mime.

(25 min)

To place salt in a world context, the teacher shows a **VIDEO FILM** to the whole class. This film shows the uses of salt in the 'Western World', but does not show sources or uses in other cultures.

(12 min)

A **CLASS DISCUSSION** follows to consider how salt is obtained outside the Western World, i.e. outside Europe, USA, Australia. The teacher explains how future lessons will fill this gap and widen students' awareness about other cultures.

(13 min)

The remaining lessons include a series of **PRACTICAL ACTIVITIES** which consider:

- Looking at three types of salt with a microscope
- Chemistry of salt – electrolysis of salt
- What salt can do:

(a) to water (b) to ice (c) to our bodies

This involves traditional **EXPERIMENTS**. When students consider how salt is used in the world, a **TAPE RECORDED SCRIPT** is used. The students listen to a series of **SIMULATED REPORTS** from around the world. This takes the form of a **RADIO BROADCAST**. After each sequence the tape is stopped and students individually complete a 'box' on a **WORKSHEET**. Visual stimulators in the form of line drawings help pupils locate the correct box. This is an example of a **DART**. **INFORMATION ARTICLES** on world salt (in the form of newspapers) provide opportunities for **READING AND WRITING** work for a **WALL DISPLAY**.

The unit ends with **PROBLEM SOLVING**. The challenge issued to groups of students is 'Get some salt from the banana skin so it can be used for cooking vegetables'. After meeting the challenge students share their answers by drawing a flow chart of their ideas and way of working.

COMMENTARY	ALTERNATIVE APPROACHES
In this lesson **BRAINSTORMING** is teacher directed and controlled. It generates ideas. It is a shared experience and provides information to the teacher about the ideas students hold about salt before the lesson proceeds, i.e. the teacher can develop the lesson from where the children are in their thinking.	**BRAINSTORMING** can also take place in **SMALL GROUPS** (e.g. 4 - 6). One student can write down the group's answers in a short specified time, usually five minutes maximum. The teacher can coordinate responses from the group recorders and write them on the blackboard or overhead projector. Alternatively, the lesson could be started where individuals write down their own ideas in a **BUZZ SESSION**. Then, in pairs, ideas are exchanged and discussed in small groups.
SMALL GROUP DISCUSSION occurs when children plan their **MIME**. It is an effective way of involving all students in ways which are non-threatening. It exploits a strength of most children; their ability and enjoyment of talking. Language, self-confidence, cooperation and tolerance of another person's point of view are fostered.	**HINT CARDS** are a good resource. The same cards could be written in a range of appropriate languages and could also combine illustrations of what was required in the **MIME**. Alternatively following the mime children can be asked to represent their ideas in a picture. This could be done in art and later displayed in the main entrance to the school. Such **CROSS-CURRICULAR** work is a powerful way of deepening a student's understanding or awareness about salt or any other resource. Topics which are appropriate in a multicultural context, like building materials, design of homes, energy sources, food, could provide a vehicle for **VISUAL DISPLAYS** and **MODEL MAKING**.
MIME is a form of **DRAMA**. It is an excellent medium for enabling students to demonstrate understanding of ideas and concepts by expressing their ideas as a series of actions they have thought out. It extends ideas into new contexts and is enjoyable to many students. In multicultural schools mime is a non-verbal way of expressing ideas and helps to unite students' thinking, where language may be a barrier.	
Use of professional **VIDEO** film is a useful motivator and is an easy way of bringing the outside world into the classroom. It helps the teacher to raise issues for **DISCUSSION**.	Another way of using **VIDEO** is to give students specific points to focus upon for different sequences of the film. The film can be stopped at appropriate points for students to record responses - it can be used interactively, starting with individuals and then sharing ideas with a partner. This makes watching TV into a more **active** form of learning. Interactive use of TV and radio is currently being developed by the BBC ('Mindstretchers'), and the IBA ('Scientific Eye').
CLASS DISCUSSION is both a familiar and efficient way of outlining the purpose of future lessons.	**DARTS (Directed Activities Related to Text)** can also be used to foster cooperation between students by sharing one worksheet between two. This encourages further **DISCUSSION** until agreement is reached upon an answer.
This use of a **TAPE RECORDING** develops ideas on how and where salt is used in the world. Using a **VISUAL WORKSHEET** for completion by students is a novel adaptation of the **DART** technique.	
Science is an activity based upon practical processes such as **PROBLEM SOLVING**. By presenting problems which are open ended opportunities for **SMALL GROUP DISCUSSION**, cooperative planning and sharing responsibility for the work are offered to students.	A range of **CROSS-CURRICULAR** approaches are relevant here. If the teacher wishes to **SIMULATE** the ways in which other cultures might extract salt from plants, students could begin by an **INFORMATION SEARCH** in the library. Library staff may have to acquire additional resources, so forward planning is essential. From this information students could use **CRAFT WORK** to **DESIGN AND MAKE** cooking and filtering vessels in clay. The banana skins could be boiled in pots which have an authentic design and students may gain a deeper understanding of life in other cultures. Self esteem can be enhanced by a **PUBLIC DISPLAY** of their science, design and craft work. The technical and scientific new words which arise in this or any other work can be stencilled in large letters and displayed randomly to make an attractive **WORD BOARD**. This will enhance students' language development.

COMMENTARY AND APPROACHES IN OTHER EXEMPLARS

In another multicultural project, at the MELS Centre in Oldham, the aim of the work is to develop positive attitudes towards oneself and others. In attempting to achieve greater trust, self-confidence and tolerance teachers select different approaches to learning and discuss issues of race and racism in a **CROSS-CURRICULAR** context.

DISCUSSION in large and small groups is used to sharpen the skills necessary to **HANDLE INFORMATION** objectively. Time is provided for sharing feelings and problems in a large **'SHARING CIRCLE'** before beginning tasks in small groups. An area of the room is designated as a 'withdrawal area' for this activity. In such groups, students are given a game to play called 'Globingo'. This involves gathering information from each other. Students ask one question per person. If the answer is 'yes' a box can be filled in on the Globingo card. As an example, the student might be asked to find someone who:

1 enjoys eating food from another country;
2 is wearing something from another country;
3 has a parent who was born in another country.

When the card is complete the student shouts 'Globingo'. This approach can be adapted for multicultural thematic science to broaden scientific knowledge and to provide an awareness of cultural differences, whilst simultaneously developing confidence in communication. Teachers from the centre report that **GROUP DISCUSSION** is particularly successful if used regularly and not in isolation. Success is **EVALUATED** by an increase in each student's contribution to lessons and enthusiasm for new approaches to learning.

The Leicester SSCR Group's *Science Education for a Multicultural Society* is an excellent resource for teachers to use to develop a multicultural approach to science teaching. It could enrich the science education of all young people. Science is a multicultural activity and this product includes a section on scientists from all parts of the world. This helps give a sense of positive esteem to students from ethnic minorities by recognising the achievements made by people of similar backgrounds to their own. Information on Afro-American, Indian and Bangladeshi scientists is provided as a resource and ideas are provided for approaches to using the resource in the classroom.

In this example information about Charles Richard Drew, an Afro-American scientist who invented blood banks, is provided on three different sheets (A,B and C) which will actively involve students in learning. The teacher divides the class into **THREE GROUPS** and gives each group a different **INFORMATION SHEET**. A pro forma type **WORKSHEET** is given to each student and s/he is asked to complete as much of the question form as possible using the information sheet. This is followed by **DISCUSSION** of answers produced by group members. The group then splits up into twos or threes and interchange with other groups so that each new group includes members with answers derived from sheets A,B and C. They now **SEEK INFORMATION** from each other to complete their worksheet. Notes can be used for writing about Charles Drew's life.

This teaching approach links oral and reading skills and provides practice in **STUDY SKILLS** which might be useful for project work. It is another example of a **DART**.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar evidence supplied by SSCR working group *Science for a Multicultural Society* by J. Hancock and J. Holmes.

Further exemplars supplied by Ms S. Bourne, Head of 'Multicultural Education and Language Service', Oldham, Lancs.

Other resources: Thompson, B. SSCR working group *Science Education for a Multicultural Society*, Leicestershire LEA. 1986.

Additional information on materials relevant to cross-cultural science can be obtained from Professor Iolo Wyn Williams, Third World Science Project, School of Education, University College of North Wales, Bangor, Gwynedd.

For further ways of using DARTS, see

Hayden, J. SSCR working group *Reading for Understanding in Science*.

Hooper, D. SSCR working group *Reading for Understanding in Science*.

Bulman, L. *Teaching Language and Study Skills in Secondary Science*, Heinemann, 1984.

Davies, F. and Greene, T. *Reading for Learning in the Sciences*, Oliver and Boyd, 1984.

Educational broadcasting materials

Granada Television: *Chemistry in Action* has two useful programmes entitled *Chemicals from Salt I* and *II*.

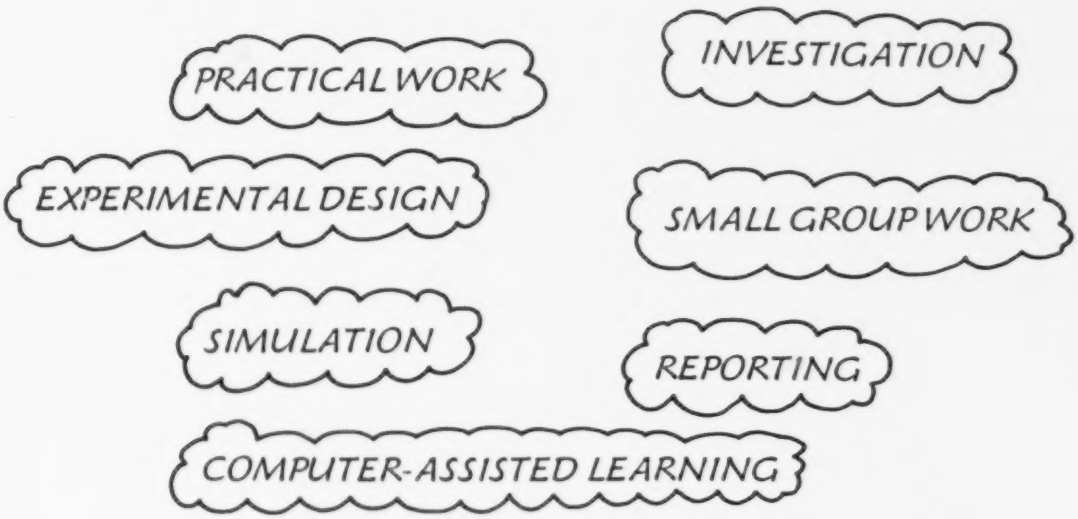
COMPUTER-ASSISTED LEARNING FOR BIOLOGISTS

PURPOSE

To show ways in which the computer and software packages can be used to enhance **PRACTICAL WORK** by access to a computer terminal in the corner of the laboratory.

SYNOPSIS

This is a scheme of work for mixed ability fifth-year Biology students on the action of enzymes. In **PRACTICAL WORK** on enzyme action it can take a long time to collect enough results from which to interpolate and extrapolate and hence predict a relationship. If students are also to be asked to plan their own **EXPERIMENTS** rather than follow a set menu, fewer results may be taken. Pooling of results is one possible solution but this assumes that the parameters and conditions in all experiments were the same and thus limits the range of results which can be used. Suppose the purpose of the experiment is changed. Instead of collecting results to produce a relationship, the purpose becomes that of **DESIGNING AN EXPERIMENT** and comparing the results with the known relationship. This permits a wider variety of parameters to be investigated in a given time. The computer can **SIMULATE** the mathematics of the relationship and allow the students to compare their results.



WAY IN

'HAVE COMPUTER IN CORNER, WILL USE IT' – fifth year option group

PLANNING

During the previous week's lesson, the 30 students have been given a task to think about. This would require them to plan, in pairs, an **INVESTIGATION** into the effects of either a change in temperature, pH or starch concentration on the action of amylase. Within three days, they would have had to list the apparatus they would need and see the laboratory technician to discuss what was available.

Because of the constraints on time, apparatus and materials, not to mention space, the students would have to see the need to try to assess the activity at only three different points. Here, the teacher encourages, advises and suggests where the need is seen. Marking or assessing is not appropriate. The computer is then used to extend the small range of measurements which they could make in one session of **90 minutes**.

All fifteen pairs of students check and set out apparatus, while the teacher and technician help to organise space and safe working (**10 min**).

PRACTICAL WORK continues (**30 – 40 min**).

As the pairs of students have now completed some of the enzyme assays, they can go at any time to the computer which is loaded with the program ENSKIN. The teacher helps to set the parameters of the **SIMULATION** which will match those used by the pair (for example, enzyme and substrate concentration and temperatures are constant but pH varies from 4 to 11) (**15 min**).

The computer will **SIMULATE** the whole range of tests similar to the students' own work, giving a table or graph curve of results. Each pair can then place their results on (or near!) the curve and produce an overhead transparency for **REPORTING** to the rest of the group.

COMMENTARY	ALTERNATIVE APPROACHES
Opportunities for many of the usual learning situations which **PRACTICAL WORK** affords are here: • **PAIRS WORKING TOGETHER** encourage students' language development in **EXPLAINING THEIR IDEAS** to each other. Listening carefully and thus modifying thinking helps to clarify ideas. • **DESIGNING AND PLANNING** their own work enables the student to accept responsibility for the end result. There is a less didactic, more subtle role for teacher – one of collaborator, not just directing and monitoring. (**30 – 40 min**).	A less structured, more open-ended way is to simply ask the students how they would show that whatever removed the starch is an enzyme (i.e. had enzyme characteristics) and not an inorganic catalyst, an acid, a base or as a result of heat.
The additional element is that the computer is used as another piece of apparatus, not as a replacement for an experimental investigation. The computer can extend each situation where necessary, allowing for different levels of expertise and speed of working (**15 min**).	If the computer program could be used before the lesson, it would show the need to keep all other factors constant if the effect of varying one factor is to be seen, i.e. it would help the students to plan a **PROPERLY CONTROLLED EXPERIMENT**.
Having an overview of the whole range of the enzyme's action helps to give a better idea of how enzymes work than could be gained from their own isolated points of measing. This demonstrates clearly that enzymes have specific pH and temperature optima, even if the students miss these in their own results (**30 min**).	The exemplar did not show the use of computers in the laboratory as a means of collecting experimental results, 'datalogging' as it is called. All the major science equipment manufacturers produce interfaces and software. The main advantage is that measurements from several different sources can be taken quickly. Many opportunities exist at sixth form level but experiments for lower school which are educationally valid and cannot be done by conventional recording instruments have not yet really been developed.
REPORTING to the whole class is made more worthwhile when the complete set of figures is available. The need to organise, present and explain results helps students to a better understanding of what is going on when an enzyme handles a substrate. It also helps them to see their own work as part of a coherent whole.	When a printer is available, the teacher can request the results as a table only, so that students could practise sketching, not plotting, their own graphs, showing the general trends or features of the reactions.

COMMENT AND SUMMING UP

In this exemplar the computer package is not being used in isolation but as part of an overall teaching scheme. In many ways it has the same function in science as **PRACTICAL WORK–INVESTIGATION**, experience, decision making, change of parameters. To use a computer package effectively requires the teacher to be familiar with the software and to be prepared for the 'hassle' of arranging to use the computer facilities available, which in many schools is not as convenient as it should be. In deciding whether or not a given computer-based learning package is worth the effort required to use it effectively, the following questions should be considered.

1 Does it develop a student's concepts of a dynamic process visually?
2 Does it only replace an existing method or can it be used to develop additional concepts or extend understanding?
3 Will it develop abilities not possible by other means?
4 Will it allow students to explore concepts in a way not envisaged by the teacher and in a way directed by the learner?
5 Does it take up too much time for the end result?

There is now an expanding range of software in all branches of science. Many publishers operate an inspection service and it is always a good idea to evaluate the software before you buy. Remember that software does take longer to evaluate than textbooks.

There are two main ways in which a program can operate:

1 Once loaded the program does not make any further use of the disk drive.
2 The program frequently uses files of data or complex screen diagram which are stored on the disk.

With a 'stand alone' machine there is no problem, but in using a network in which many computers share a common disk drive the speed of access is much slower. This means that programs which frequently 'access' the disk often appear to stop working because someone else is using the disk drive. Special network versions need to be produced.

The exemplar has only shown 'educational' packages. One area now being developed is the use of 'content free' software. This includes:

- **WORD PROCESSORS**–writing experimental reports, writing a description of a process or an explanation. The advantage of word processing is that you can change your mind. Text can easily be corrected, you can go back and put in extra text, and you can change the order. It can help students to structure their thoughts logically.
- **SPREADSHEETS**–an electronic table of results on which calculations can be done easily.
- **DATABASES**–for storing information. Using a database can help students to realise the nature of information and to search for patterns more easily, particularly when there is a lot of information.

Much software is written to help in the teaching of specific concepts. Many packages now link with TV programmes, audio tape and other visual or learning materials. The opportunities for more independent and interactive learning activities are there if we wish to explore them.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by Anita Pride, Bruntcliffe High School, Leeds in collaboration with Trevor Cross, Great Sankey High School, Cheshire.

Program ENZKIN (Enzyme kinetics) from Chelsea Science Simulations, Edward Arnold, 1977 (out of print)

There are a great number of suppliers of educational software. Recently some companies have produced comprehensive catalogues of software. The person responsible for computing in your school will certainly have them.

BBC Education materials with broadcast dates

Science Topics (TV), *Catalysis*, Autumn 1986

Science Topics (TV), *Biotechnology*, Autumn 1986

Biotechnology (Radio Night Time Broadcasts), Summer 1987

Other educational broadcasting materials

Granada Television: *Chemistry in Action* has some computer simulation software to enable young people to make decisions about manufacturing processes.

Granada Television *The Micro at Work* contains further useful material.

SCIENCE THROUGH A TECHNOLOGICAL AND VOCATIONAL CONTEXT

PURPOSE

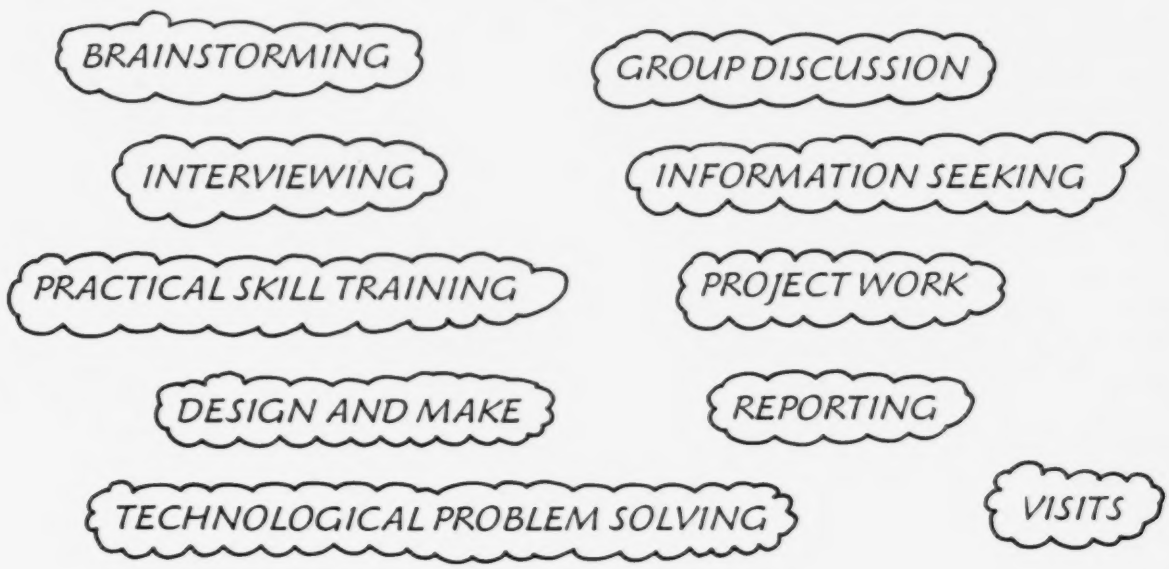
To develop an appreciation of the application of scientific ideas and methods within the broad context of 'real life' **PROBLEM SOLVING EXERCISES**.

SYNOPSIS

This exemplar explores the setting up of small businesses to develop an awareness of the wider world of business, management and manufacture. The manufacturing process and the testing of the product involve various scientific and technological skills and enable the students to work purposefully, freed from the constraints of subject barriers and timetable divisions. The **PROJECT** described is a year-long exercise used with sixth formers of mixed abilities but could be adapted for a shorter period. It is extremely flexible and adopts an overall approach which allows students to become very involved in their own learning. The aim is for students to feel a greater sense of achievement and self-pride through their involvement in a project which is relevant to their needs.

In this situation a variety of alternative approaches is particularly appropriate. The long term nature of the **PROJECT** means that a number of approaches can be used several times.

A second exemplar is featured which deals with a rather shorter, more conventional approach to the wider world which outlines a 'task week' for students in their final year of school.



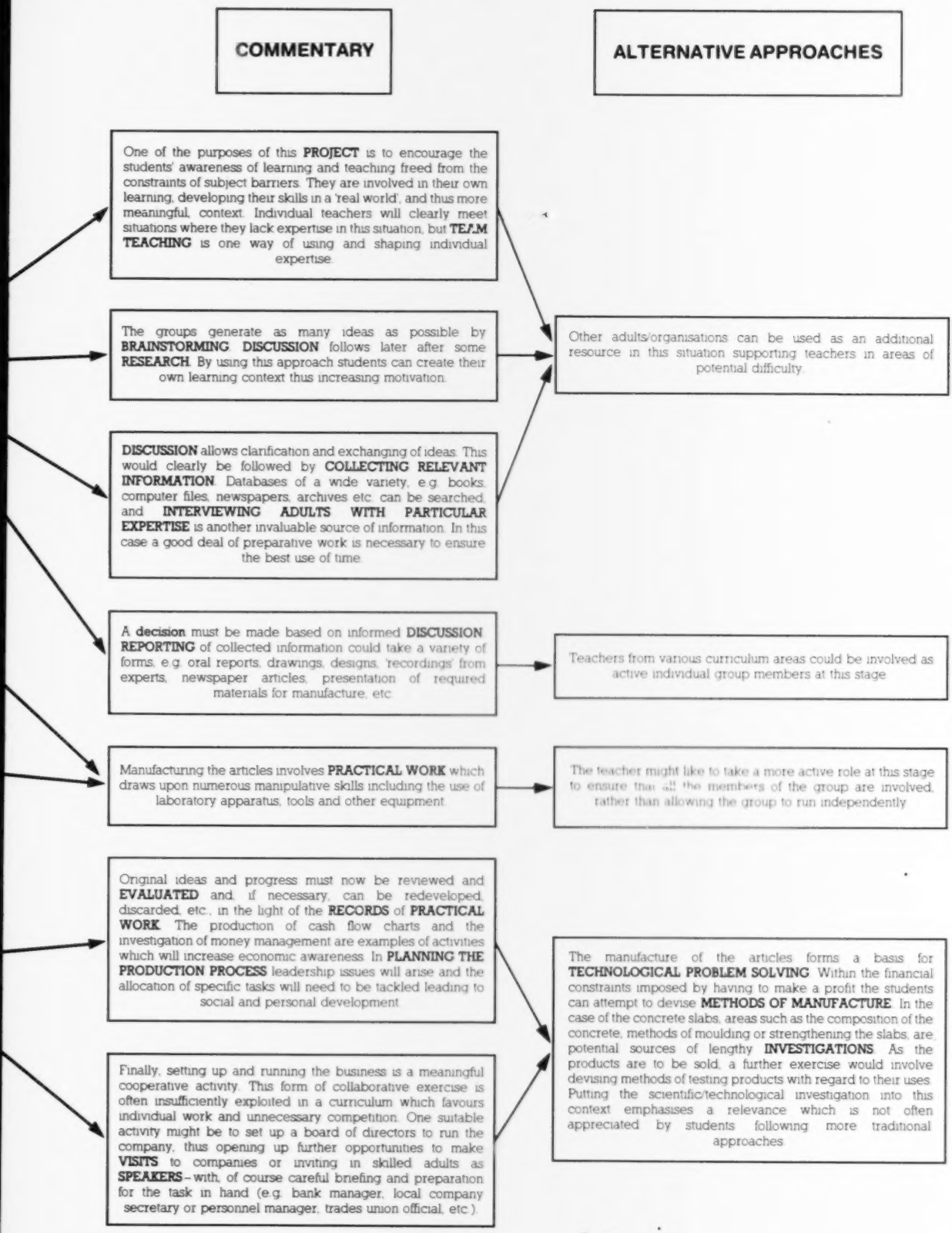
WAY IN

At the beginning of the project the scheme is outlined to the students and the rationale for the scheme is explained. Potential small business ideas are generated by **BRAINSTORMING** and are then more fully considered in **GROUP DISCUSSION**. A selection of 'credible' schemes for fuller practical investigation takes place at this point, involving the students in a great deal of **INFORMATION SEEKING** and possibly **INTERVIEWING** of individuals with particular expertise. In reaching a decision the problems of locating, costing and management of resources is fully **INVESTIGATED** and a great deal of **REPORTING** and **GROUP DISCUSSION** occur.

In the particular school concerned the small 'firms' decided to focus on the production of concrete slabs for gardens, cast resin chess sets, decorative candles, enamelled copper jewellery and bead and leather jewellery. Owing to the variety of products to be manufactured there is no fixed learning situation. It includes a classroom, a laboratory and a workshop.

The next stage is to identify the necessary resources. The ideas are then **TESTED PRACTICALLY**. The methods of manufacture and the products themselves are **INVESTIGATED** and this involves a great deal of **PRACTICAL WORK** which develops scientific and technological skills. The final stage is deciding/designing the method for **MAKING** the final product. During this process **VISITS** can be appropriate as a way of generating ideas or seeking expertise.

A review of the groups' progress now takes place, involving more **REPORTING** and **GROUP DISCUSSIONS**, and a final **PRODUCTION PROCESS** is planned. The final stage is setting up and operating the business. The groups organise their own activities and are responsible for their own finances and personnel problems. They deal with the day-to-day running of the business, manufacture the product and market it.


COMMENTARY
ALTERNATIVE APPROACHES
One of the purposes of this PROJECT is to encourage the students' awareness of learning and teaching freed from the constraints of subject barriers. They are involved in their own learning, developing their skills in a 'real world', and thus more meaningful, context. Individual teachers will clearly meet situations where they lack expertise in this situation, but TEAM TEACHING is one way of using and shaping individual expertise.
The groups generate as many ideas as possible by BRAINSTORMING. DISCUSSION follows later after some RESEARCH. By using this approach students can create their own learning context thus increasing motivation.
DISCUSSION allows clarification and exchanging of ideas. This would clearly be followed by COLLECTING RELEVANT INFORMATION. Databases of a wide variety, e.g. books, computer files, newspapers, archives etc. can be searched, and INTERVIEWING ADULTS WITH PARTICULAR EXPERTISE is another invaluable source of information. In this case a good deal of preparative work is necessary to ensure the best use of time.
Other adults/organisations can be used as an additional resource in this situation supporting teachers in areas of potential difficulty.
A decision must be made based on informed DISCUSSION. REPORTING of collected information could take a variety of forms, e.g. oral reports, drawings, designs, 'recordings' from experts, newspaper articles, presentation of required materials for manufacture, etc.
Teachers from various curriculum areas could be involved as active individual group members at this stage.
Manufacturing the articles involves PRACTICAL WORK which draws upon numerous manipulative skills including the use of laboratory apparatus, tools and other equipment.
The teacher might like to take a more active role at this stage to ensure that all the members of the group are involved, rather than allowing the group to run independently.
Original ideas and progress must now be reviewed and EVALUATED and, if necessary, can be redeveloped, discarded, etc., in the light of the RECORDS of PRACTICAL WORK. The production of cash flow charts and the investigation of money management are examples of activities which will increase economic awareness. In PLANNING THE PRODUCTION PROCESS leadership issues will arise and the allocation of specific tasks will need to be tackled leading to social and personal development.
Finally, setting up and running the business is a meaningful cooperative activity. This form of collaborative exercise is often insufficiently exploited in a curriculum which favours individual work and unnecessary competition. One suitable activity might be to set up a board of directors to run the company, thus opening up further opportunities to make VISITS to companies or inviting in skilled adults as SPEAKERS – with, of course careful briefing and preparation for the task in hand (e.g. bank manager, local company secretary or personnel manager, trades union official, etc.).
The manufacture of the articles forms a basis for TECHNOLOGICAL PROBLEM SOLVING. Within the financial constraints imposed by having to make a profit the students can attempt to devise METHODS OF MANUFACTURE. In the case of the concrete slabs, areas such as the composition of the concrete, methods of moulding or strengthening the slabs, are potential sources of lengthy INVESTIGATIONS. As the products are to be sold, a further exercise would involve devising methods of testing products with regard to their uses. Putting the scientific/technological investigation into this context emphasises a relevance which is not often appreciated by students following more traditional approaches.

COMMENTARY AND APPROACHES IN OTHER EXEMPLARS

An alternative method of bringing students into contact with the wider world was attempted by a school which introduced a 'Task Week'.

A great deal of preparation, through active tutorials, was done for the 'Task Week'. This included exercises in developing sensitivity to others, exploring similarities and differences in individual values, exploring emotions, developing listening skills, observing how others behave, and participating in group decision making. Various skills were also practised, for example using the telephone, and an exercise was developed to help individuals decide the kind of work situation they would like to experience.

The 'Task Week' itself involved the students working with employers on specific tasks which would give them some idea of the needs of industry and an understanding of what would be expected of them when they left school.

In terms of development of scientific and technological skills, the tasks would need to be carefuly chosen and negotiated with the student and the employer. However, the opportunities for relevant experience are many and various. It is also an opportunity to provide a different activity from work experience in that it would not simply be about carrying out a routine job for a week, but could be related directly to a specific task negotiated between student, teacher and employer.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplars supplied by Ms S. Marks, Glan-y-Mor Comprehensive School, Dyfed, Wales.

Exemplar supplied by Ms M. Barry, Ursuline Convent School, Wimbledon, London.

Smith, D. and Wootton, R. *Exploring Enterprise: School and Business Perspectives*, Longman Resources Unit, York, for SCDC Publications, 1986.

BBC Education materials with broadcast dates

Economics: Case Studies in Production (Radio Night Time Broadcasts), Autumn 1986

Technology and Design (Radio and TV), Spring 1987

Other educational broadcasting materials

Thames Television. *Craft, Design and Technology* has some programmes for 14 – 16 year-olds which follow the above theme – especially programmes Five and Six concerning designing and marketing a product.

SCIENCE VISITS OUT OF SCHOOL – ENVIRONMENTAL FIELD EXCURSIONS

PURPOSE

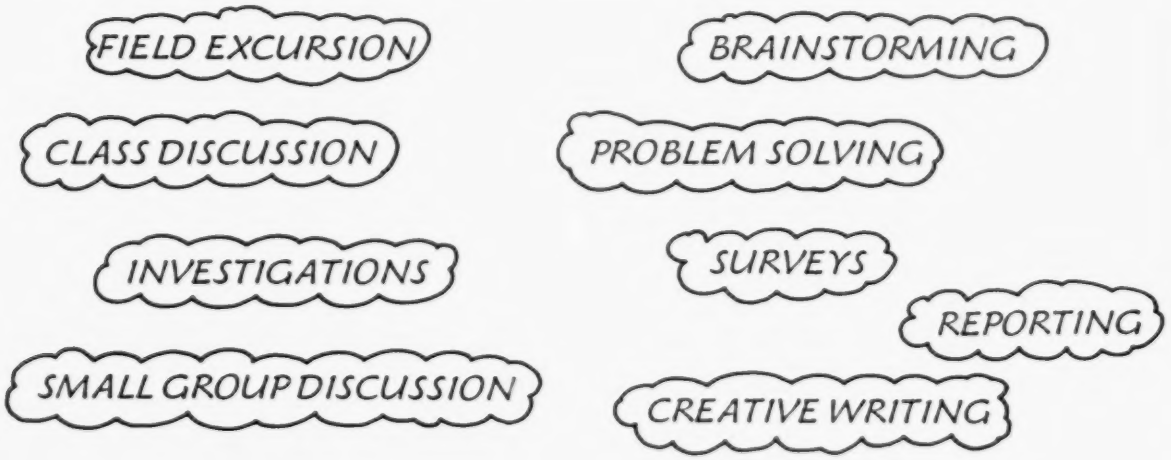
To provide stimulation through first-hand experiences which are relevant and arise out of the children's own environment. To develop an awareness of the environment and human interaction with it.

SYNOPSIS

This **FIELD EXCUSION** is based on a series of **VISITS** during September and October to the same woodland area by 26 boys and girls aged 9–11 accompanied by their class teacher and a parent with a teaching qualification. Initial **ORIENTATION VISITS** provided a basis for more detailed studies involving students in measurements, observations, recordings, etc. The study is completed by a **REPORTING BACK SESSION** in the classroom involving all the students.

The exemplar lists outcomes in terms of small group skills such as talking, observing, measuring, estimating, communicating and discussing and attitudes such as cooperation, enthusiasm, questioning, willingness to be involved, tolerance and confidence.

The conceptual outcomes relate specifically to food chains and interdependence, yet far more has been achieved by the purposeful use of a range of approaches. Experiential learning is often restricted to lower age groups, yet it is stimulating to pupils in the whole range of secondary education for whom this approach would be equally applicable. **FIELDWORK** in this instance is used as the context or setting for a wide range of activities such as **BRAINSTORMING**, **CREATIVE WRITING**, **DISCUSSION**, etc. in conjunction with **PROBLEM SOLVING**, **SKILL TRAINING** and the more typical science-based **INVESTIGATIONS**.



WAY IN

The study took place in a woodland area in the locality of the school and students became involved in a number of **PRELIMINARY VISITS** in July in preparation for subsequent visits in September and October. During these visits allowance was made for the inevitable spontaneous sources of excitement and on each occasion the class returned to the school with **COLLECTIONS** of a wide variety of organisms and objects. As part of the actual tree **SURVEY** the children were to use pooters. Because of the unusual nature of this piece of apparatus, one preliminary visit involved the capture of many insects and other organisms, all of which were released following identification. This exercise was so successful that it formed the basis of another topic.

Once a familiarity with the woodland area had been established the main purpose of the activity was introduced. The direction the tree survey might take was **DISCUSSED BY THE WHOLE CLASS** and a **FLOW CHART** was built up by teacher and students together using the overhead projector. The children were encouraged to talk within their **SMALL GROUPS** and develop the flow chart further. Concepts such as food chains and interdependence of living things, habitat and adaption to ecological niche were explored.

Having done this the children were asked to **DISCUSS** possible strategies for making recordings, measurements and collections. The exemplar describes how the children embarked on their studies utilising limited resources at a 'base camp'. Their studies were initially guided and supported by the teacher to ensure all/most tasks were completed.

Back in the classroom each group elected a spokesperson to **REPORT** their findings to the rest of the class. Time was not limited unnecessarily and the teacher directed the **DISCUSSION** to ensure that the session included questioning of individuals within the group by their peers. Later the children wrote up their field notes and developed working sketches. Work completed was **DISPLAYED** and comparisons between the different group findings were made possible by the display being presented around a number of key questions.

It was decided that further visits to this area should be undertaken to investigate the long-term changes which take place at the site, so that the tree survey will be continuous into the future as part of school work and perhaps lead to a life-long interest in this location. The site was re-visited in the late Autumn and in the middle of Winter for further **INVESTIGATION** and **DATA COLLECTION**.

COMMENTARY	ALTERNATIVE APPROACHES
In this initial phase students must come to terms with the purpose of the activity. The exchange of ideas and personal experiences provided in the **PRELIMINARY VISITS** allow students and teacher to share the wonderment of nature on an **exploration** and to move towards a reason for further scientific studies.	The main reasons for **FIELD EXCURSIONS** are to provide students with an opportunity to apply their studies to real situations; and to cultivate an awareness of the environment and human interaction with it. Nothing can replace 'hands on' experience, but awareness of the environment can be further promoted by the use of relevant **COMPUTER-ASSISTED LEARNING** packages which are commercially available. **SIMULATIONS** involving **DECISION MAKING** and **ROLE PLAY** can help the students to simulate and appreciate the difficulties involved in making decisions with ecological consequences.
Although the teacher identifies the main purpose of the **FIELD EXCURSION** in terms of outcomes such as skills and concepts, an attempt is made to provide an adequate basis of trust and to **negotiate** the specific nature of the tasks so that the purposes are not alien to the students. The resulting development using **CLASS DISCUSSION** as a way of producing a direction for the study involves the pupil in more decision making about his/her learning.	**ROLE PLAY** may also be used in the form of a **MOCK ENQUIRY** over the future use of an area of land. Students in the role of conservationist, property developers, farmers, etc. put forward their arguments and evidence as to **why** their plans should be adopted. The class can vote at the end as to who was the most convincing.
The subsequent **DISCUSSION** in **SMALLER GROUPS** provides the students with opportunities to clarify their own ideas through **LANGUAGE ACTIVITIES**. The clarification should be found in the range of concerns about wildlife, growth and changes in a habitat with time. This would be demonstrated in the flow charts they produce. The approach again places the student in a more active role and provides situations whereby the student is developing a much wider range of skills and ideas.	Repeated personal contact with nature is likely to modify a student's view of how humans and the environment affect each other. The high level of interest generated by the media and **EDUCATIONAL BROADCASTING** concerning pollution and other ecological issues may be used to stimulate lively classroom **DEBATE**. Any discussion on the increasing threat posed by technology should be balanced by focusing on the benefits technology brings to our lives. This in turn could motivate students to undertake their own evaluation of any given situation by using libraries to **COLLECT INFORMATION** or by **DESIGNING AND PERFORMING** their own **INVESTIGATIONS**.
DECISIONS MADE BY STUDENTS about the specific nature of scientific studies involving observation, measurement, recording, etc. are not always considered necessary by teachers. By allowing time for the students to **DESIGN EXPERIMENTAL INVESIGATIONS** they gain an awareness of the purpose for the measurements and observations made. The context of a **PROBLEM SOLVING SITUATION** involving the sharing of limited resources of a 'base camp' (such as tape measures, clinometers, pooters, scissors, collecting jars, magnifying glasses, trays for collection, squared paper, ...) adds a further dimension of complexity.	Little account is given in this description of the practical investigations, yet the skills and processes are central to the development of scientific abilities whatever the context. In the use of **PROBLEM SOLVING** approaches, **INFORMATION FINDING** in relation to establishing the nature of the problem can itself provide opportunities for the development of the ability to handle, interpret and evaluate information relating to environmental situations not normally accessible to pupils.
In the final stage of the exemplar attitudes such as responsibility, perseverance, confidence, the ability to share experiences with others are all felt to be important. The value given to **STUDENT'S REPORTS**, which took many forms, is emphasised by the allocation of time by the teacher. The appreciation of the cooperative venture of a class study provided a basis for further developments of skills, processes and attitudes in the **FINAL REPORTING SESSION**.	**REPORTING** gives a student the opportunity to express his/her own interpretation of an experience. Alternatively **DRAMA**, **CREATIVE WRITING** or **POETRY** could be the form of expression chosen. Such approaches are not intended to substitute for the information transfer type of report, but are advantageous in that they allow the students to communicate their perceptions and interpretations of situations and problems. A field excursion can be used to help students to link 'new' ideas with their prior knowledge, to predict likely outcomes of similar studies, to be sceptical and to make judgements independently of the teacher.

COMMENT AND SUMMING UP

FIELD EXCURSIONS enable students to have first-hand scientific experience of the natural environment, making their studies more immediate and meaningful. Students need to develop both scientific and interpersonal skills, especially where team work is involved. Distant sites may be chosen for such visits but local areas, whether school grounds, local urban open spaces or nearby countryside, allow multiple visits and involve less organisation than residential field studies, offering students the opportunity to view a familiar place in a new light.

In this exemplar, the relationships between the environment, technology and pollution are examined for a particular area through time. **ROLE PLAY** such as the mock public enquiry is a useful follow on activity, encouraging the students to put forward their views as logical and convincing arguments, while gaining an insight into the complexities of environmental usage. **COMPUTER-ASSISTED LEARNING** packages develop a student's decision making abilities by providing **SIMULATIONS** that let them see the consequences of their actions. It is hoped this will cultivate a caring and more constructive attitude to the environment.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by Mr S W. Garbett, Hayland Elsecar Church of England Junior and Infant School, Elscar, Barnsley.

Relevant SSCR working groups and their convenors.

Garner, P. *Environmental Science*

Garner, P. *Biological Science*

Johnson, J. *Primary Approaches to Secondary Science*

Logan, J. *Local Environments as Contexts for Learning in Science – Science and our Local Rocks*

Logan, J. *Local Environments as Contexts for Learning in Science – Investigative Science in the Natural Environment*

Logan, J. *Local Environments as Contexts for Learning in Science – Science in the School and Home Environments*

Mills, D. *Fieldwork Data Collection*

Pitt, B. *Developing Practical Experimental Work for Use in Environmental Courses and Modules*

Williams, A. *Man and the Environment*

Other sources

The Field Studies Council.

The Urban Spaces Scheme produces booklets to help teachers with ecological class projects including: *Ecology in the City; Urban Plant Ecology; Plants of Walls and Pavements; Minibeast Mix and Match; Teaching from Tree Planting; Planning a School Nature Garden; Colour and Minibeasts.* For further information and advice please write with s.a.e. to Urban Spaces Scheme, Department of Food and Biological Science, Polytechnic of North London, Holloway Road, London N7 8DB.

The Association for Science Education Rural Science Working Party, c/o ASE.

BBC Education materials with broadcast dates

Science Topics (TV), *Ecology and Conservation*, Autumn 1986.

Plus linked Software Pack (same title) available from BBC Publications, Software Department, 35 Marylebone High Street, London W1M 4AA.

Other educational broadcasting materials

Granada Television: *Science Visits I, Geography at 16+*; programmes show field visits and other approaches to observing the environment.

Yorkshire Television: *Scientific Eye*; *ACIDS* explores human interaction with the environment.

SCIENCE VISITS OUT OF SCHOOL – METEOROLOGY

PURPOSE

To develop knowledge and concepts of the science of weather within the context of a visit. A **VISIT** to a meteorology station was used as a focus for introducing and developing learning situations.

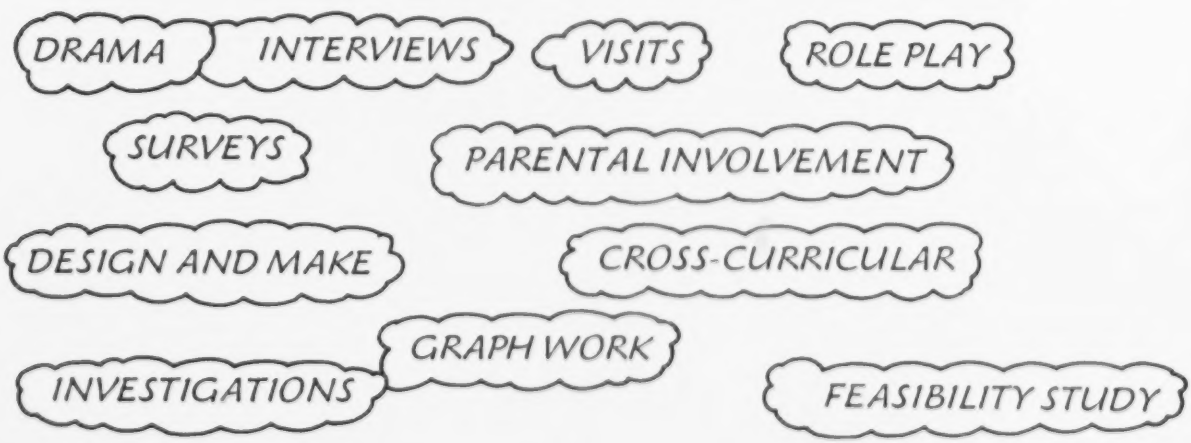
SYNOPSIS

Are you looking forward to your next science class? Are the students? Whatever your answer this section is for you.

Certain learning opportunities in science could be described as **events**. **FIELD TRIPS**, **VISITS**, **OUTSIDE SPEAKERS**, **OPEN DEBATES** on issues, etc. These are activities which entail specific pre-planning and which you may use to good effect. Each of these activities has an associated 'uncertainty factor' as the outcomes are not entirely predictable. Follow up work should be anticipated but not predetermined. The activity offers the students a measure of independence and an opportunity to be given responsibility, according to age and circumstances.

As with many learning situations the development of skills, processes, concepts, etc. occurs, but 'events' also offer special opportunities for the promotion of a wide range of positive attitudes. Not surprisingly, 'initial' success indicators tend to focus on enthusiasm and enjoyment on the part of students and teachers. The accompanying positive motivation can be enhanced if the event is used as a springboard for follow on activities, both within the event and beyond the confines of science. How far are you prepared to go? What approaches could you use now?

In the exemplar overleaf the 'event' happens to be a **VISIT** which involved a class of 6-year-old students from an infant school. Now if you're ready, 'take the plunge'.



WAY IN

HOW FAR ARE YOU PREPARED TO GO?

Taking the plunge

The topic 'weather studies' was selected jointly by teachers and students. Teachers decided on areas of major interest and considered possible local venues for a **VISIT** aided by resource materials (photos, guide books, etc.) and by past, recorded experiences. A weather station was suggested and agreed to by all concerned.

Planning ahead

A **FEASIBILITY STUDY** was carried out, to establish if the **VISIT** was viable and appropriate, what the students would be able to do and see, how many students could be accommodated and to find a suitable time for the visit. Transport was arranged, parents being invited to help and to accompany the group. Parental consent for the visit was also obtained and general arrangements were made.

Preparing for action

Before the **VISIT**, the topic 'weather' was developed to an appropriate point and the students were given an outline of the sort of things that they might do and see at the weather station. General safety aspects were outlined and final preparations made.

The event

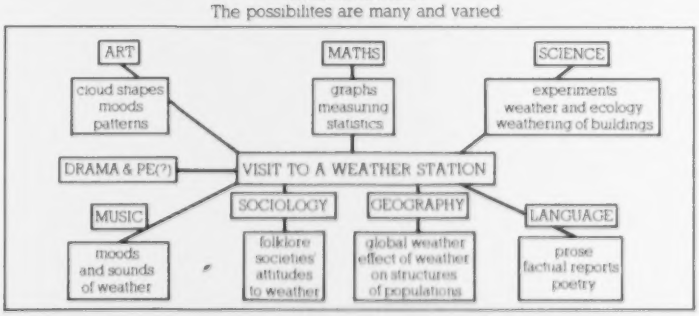
The visit was centred round a **GUIDED TOUR** given by the meteorologist to coincide with her activities of monitoring, data recording, checking, etc. the various windspeed instruments. Students were actively involved in helping and were given recently obtained data charts to take away. A **PHOTOGRAPHIC RECORD** of the visit was made.

Back home

Back at school follow up work included creating a **RECORD** of the visit. **WRITTEN**, **PICTORIAL**, **MAP** and **GRAPH WORK** were used and a **DISPLAY** was mounted. **GROUP DISCUSSION** generated many questions and ideas, some of which had not been anticipated, and this formed the basis for future work, both science-based and **CROSS-CURRICULAR**, which was relevant and interesting to the children.

Where to now?

The possibilities are many and varied.



COMMENTARY

ALTERNATIVE APPROACHES

Taking the plunge

Underpinning the selection of topic is a sense of **purpose**

- to explore the nature of the physical environment through observation, investigation and inquiry;
- to promote the development of scientific attitudes, skills and concepts;
- to provide shared experiences for students and teachers.

With a definition of purposes as the starting point, 'Weather Studies' is really the context through which to achieve these purposes, and the **VISIT** is the specific 'event' which offers a variety of learning experiences, serving as a springboard for subsequent work.

College A *Purposes*: to provide a stimulating context in which to gather and process information, to give students the opportunity to relate to and work with people of widely differing ages/situations. *Topic*: Cigarette smoking. *Event*: **INTERVIEWS** based on a survey designed by students and a **QUESTIONNAIRE** carried out in school, at home, within local community.

School B *Purposes*: to encourage the development of a range of attitudes including open-mindedness, desire to be informed, tolerance, cooperation, persuasiveness, responsibility and questioning through a relevant issue. *Topic*: The proposed extension of a local quarry close to an archaeologically important site (a fort). *Event*: A court of enquiry involving **ROLE PLAY**.

Planning ahead

The **FEASIBILITY STUDY** mentioned in the exemplar is crucial and really involves two entirely separate issues: 'Can the event, as proposed, be organised?' and, 'Are the learning experiences and activities it offers appropriate?' The latter question requires a consideration of possible approaches, e.g. **GROUP WORK**, **DATA GATHERING**, **PROBLEM SOLVING**, **DISCUSSION**, **CREATIVE WRITING**.

School C planned an event which lasted several months. Students were to conduct individual **ECOLOGICAL STUDIES** of small plots of land which would remain untouched for up to a year. The planning involved an initial meeting of teachers to establish aims, objectives and assessment criteria following which a timetable of activities was worked out. The advantage of this type of extended event is that other activities including **DISCUSSION** and assessment are interwoven with the **FIELDWORK** and this allows for an ongoing **EVALUATION** of the project.

Preparing for action

Will the students be well prepared, at the right place, at the right time? This involves ensuring that all organisational arrangements have been made and that the topic has been developed to the point where the event will be meaningful in terms of the development of students' social and cognitive skills.

School D went on a **BUS JOURNEY** to obtain distance/time data as part of their Physics course. **School E** invited two industrial research scientists to come and be **INTERVIEWED** by a fifth-year group - 'new faces', 'experts', 'real scientists', at a time which was appropriate both in terms of their science course and of a social education programme within the school. **EDUCATION DRAMA** is another kind of event which is being used within an increasing number of 'science classes'.

The event

The **VISIT** to the weather station lasted about two hours and during this time a **PHOTOGRAPHIC RECORD** was built up - opportunities for parents or students here. This can be a very valuable resource for **REPORTING** through **SCHOOL OPEN DAY DISPLAYS**, and as an aid to presenting a **VISUALLY ATTRACTIVE RECORD** of the event.

More important than the event itself are the follow-up classes which must seize upon the shared experiences of students and teachers and not become passive and prescriptive, unsupportive to the positive environment generated by the event. What has 'happened' for the pupils must form the basis for the approaches used now. **REPORTING**, for example, can be creative if unconstrained by a prescribed format. Real opportunities arise to draw from the pupils' own motivation and experiences both within and beyond science. If parents were involved in the event, have they been invited to contribute 'back home'?

Back home

The high level of enthusiasm and motivation which the students and teacher bring to class after the event is evident in immediate follow up work which must, in a real sense, be spontaneous. The permanent record which emerges is like a fingerprint, i.e. unique to the specific occasion.

Where to now?

The exemplar suggests that the **VISIT** to the weather station offers 'jumping off' points in lots of different directions within and beyond science. Specific suggestions included: **DESIGNING AND MAKING** weather recording instruments and model windmills; **CREATIVE** and **DESCRIPTIVE WRITING** about weather; **INVESTIGATIONS** into melting and freezing; **GRAPH WORK**, **DESIGNING** and **MAKING** a kite. **EVALUATION** of the real outcomes is important at this stage. Have the originally identified purposes been achieved? Would I do anything differently next time? How can I develop the approaches used?

Where to now?

A question leading to many possibilities, yet the answer surely comes from an **EVALUATION OF OUTCOMES** and teachers' 'intuitions'. Typical responses to the question 'What are the learning outcomes?', i.e. what do youngsters get out of this approach? include 'Enjoyment resulting in a positive approach to work' 'A willingness to cooperate with one another enthusiastically' (School E). 'Group once back in school worked more cohesively, cooperatively and with greater enthusiasm' (College A). The gain in terms of the development of scientific attitudes is clearly evident from the **EVALUATION** of widely varying approaches centred round 'events' in addition to cognitive development and the various other gains. If you want to enjoy your science with your students, how far are you prepared to go?!

COMMENT AND SUMMING UP

One dictionary definition of an event is 'a notable occurrence'. The term 'event' covers such a wide range of learning situations that there are many completely different types, some of which have already been discussed. An event in any form can produce a memorable and enjoyable experience complementary to other learning experiences in school classrooms or laboratories.

CLASSROOM INVESTIGATIONS or **DEMONSTRATIONS** can often be repeated but an event such as a **VISIT** represents a unique opportunity for all. Is there really an alternative to *in situ* experiences such as seeing a scientist at work, being with a scientist at work, being a scientist at work, monitoring, recording, discussing, being curious, open-minded, responsible, cooperative, respectful, tolerant, questioning, enthusiastic? The positive attitude to learning through events will encourage the learning and understanding of concepts, and has the potential for developing scientific skills and attitudes supportive of active participation by the student.

The involvement of parents in the **VISIT** to the weather station provides a positive encouragement to students both during and after the visit and has many other possible 'spin-off' advantages including the possibility of home-based **INVESTIGATIONS** and **PROJECTS**.

CROSS-CURRICULAR work emerges naturally according to the experiences of students and presents a superb opportunity for science to be represented within situations with which students can identify or co-determine. Many questions and ideas, both from the teacher and student, are generated by **VISITS** or events. Although some can be predicted, many are synthesised from the common shared experiences. At this point 'How far are you prepared to go?' becomes the real challenge.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by Mrs S.J. Fearn, Beaconsfield Church of England School, Penrith, Cumbria.

College A: Ms Sue Ely, Wreake Valley College, Leicestershire.

School B: Noel Browne, Ballyclare High School, Co. Antrim, Northern Ireland.

School C: Mrs J.Palmer, Seconded DES Research Fellow, St Peters and Merrow Grange School, Guildford, Surrey.

School D: Mr D.J.F. Lacey, Saint James School, London.

School E: Dr R.W. Buckley, South Hunsley School, Humberside.

BBC Education material with broadcast dates

Investigating Science (TV): *Problems to Solve 4: Weather Forecasting*, Spring 1987.

Other educational broadcasting materials

Granada Television: *Geography at 16+* features aspects of weather and scientific observations and records.

PARTICLES MATTER

PURPOSE

This exemplar illustrates part of a teaching scheme which has been designed to encourage students to move away from everyday notions about materials and their behaviour towards an appreciation of a particulate view of matter and the behaviour of particles in solids, liquids and gases. It also gives opportunities for students to consider the role of theories in science.

SYNOPSIS

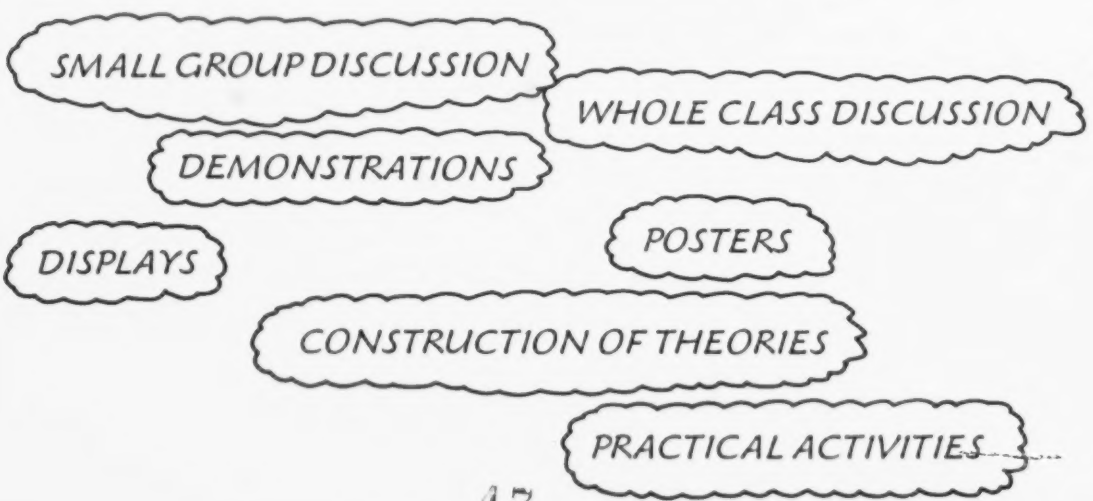
The exemplar considers a sequence of lessons intended to introduce students to the particulate theory of matter, and to the more general issue of the construction of scientific theory. The sequence, which consists of between seven and ten double lessons is intended for 13–14-year-old students of a wide range of abilities. It was developed by a group of teachers working in collaboration with the Children's Learning in Science Project andhas been tried out by these teachers.

The sequence starts with the ideas which students themselves bring to science lessons and, viewing learning as a process of conceptual changes, provides opportunities for students to extend, develop and restructure these ideas.

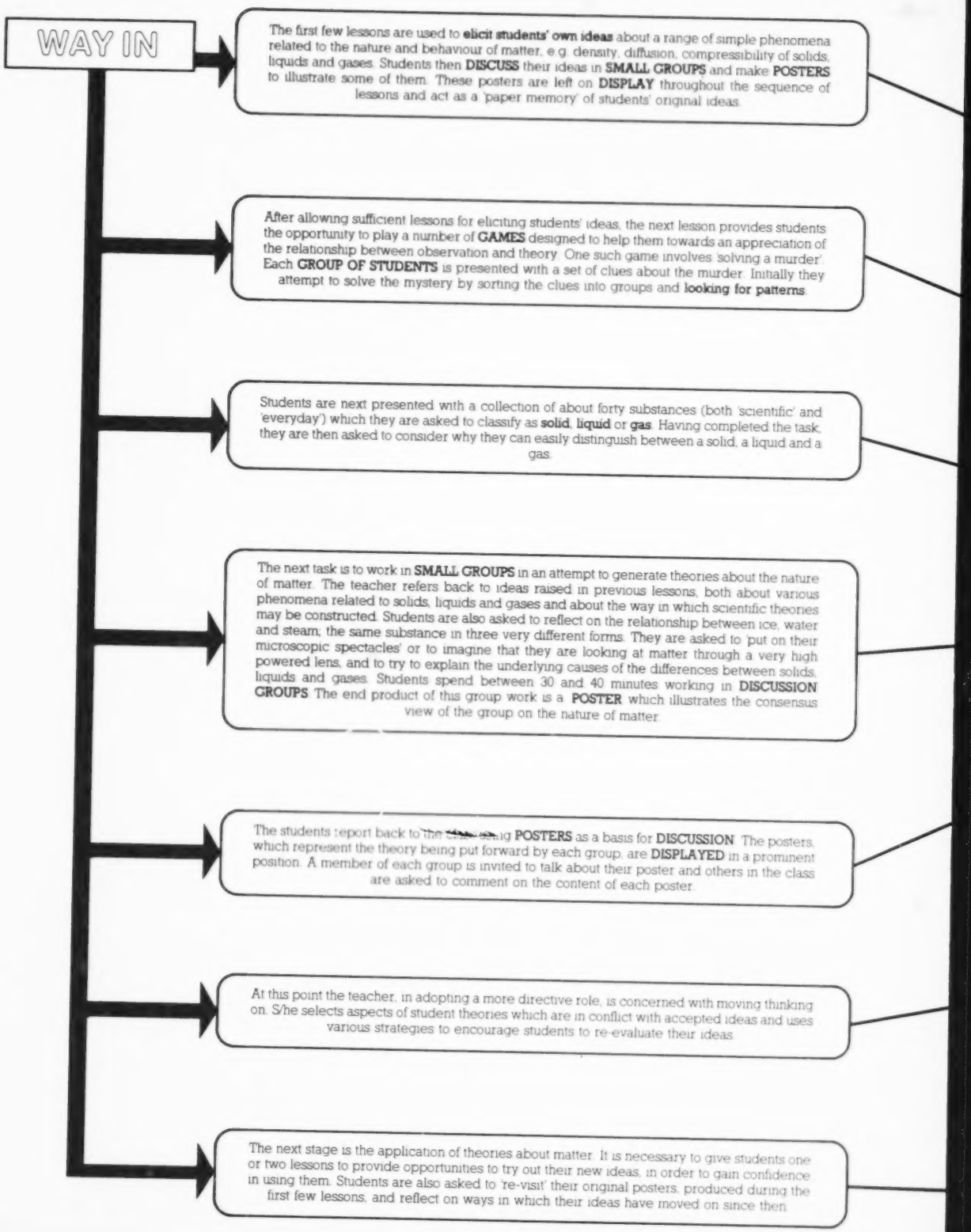
The learning opportunities which are provided include:

- giving students opportunites to make their own ideas explicit;
- providing experiences which interact with students' prior ideas;
- providing opportunities and time for thinking about new experiences, both individually and in groups;
- providing opportunities for students to try out new ideas.

Such teaching strategies require that the teacher adopts the role of adviser, consultant or facilitator, enabling learning experiences to occur.



47


WAY IN
The first few lessons are used to **elicit students' own ideas** about a range of simple phenomena related to the nature and behaviour of matter, e.g. density, diffusion, compressibility of solids, liquids and gases. Students then **DISCUSS** their ideas in **SMALL GROUPS** and make **POSTERS** to illustrate some of them. These posters are left on **DISPLAY** throughout the sequence of lessons and act as a 'paper memory' of students' original ideas.
After allowing sufficient lessons for eliciting students' ideas, the next lesson provides students the opportunity to play a number of **GAMES** designed to help them towards an appreciation of the relationship between observation and theory. One such game involves 'solving a murder'. Each **GROUP OF STUDENTS** is presented with a set of clues about the murder. Initially they attempt to solve the mystery by sorting the clues into groups and **looking for patterns**.
Students are next presented with a collection of about forty substances (both 'scientific' and 'everyday') which they are asked to classify as **solid**, **liquid** or **gas**. Having completed the task, they are then asked to consider why they can easily distinguish between a solid, a liquid and a gas.
The next task is to work in **SMALL GROUPS** in an attempt to generate theories about the nature of matter. The teacher refers back to ideas raised in previous lessons, both about various phenomena related to solids, liquids and gases and about the way in which scientific theories may be constructed. Students are also asked to reflect on the relationship between ice, water and steam, the same substance in three very different forms. They are asked to 'put on their microscopic spectacles' or to imagine that they are looking at matter through a very high powered lens, and to try to explain the underlying causes of the differences between solids, liquids and gases. Students spend between 30 and 40 minutes working in **DISCUSSION GROUPS**. The end product of this group work is a **POSTER** which illustrates the consensus view of the group on the nature of matter.
The students report back to the [illegible]ing **POSTERS** as a basis for **DISCUSSION**. The posters, which represent the theory being put forward by each group, are **DISPLAYED** in a prominent position. A member of each group is invited to talk about their poster and others in the class are asked to comment on the content of each poster.
At this point the teacher, in adopting a more directive role, is concerned with moving thinking on. S/he selects aspects of student theories which are in conflict with accepted ideas and uses various strategies to encourage students to re-evaluate their ideas.
The next stage is the application of theories about matter. It is necessary to give students one or two lessons to provide opportunities to try out their new ideas, in order to gain confidence in using them. Students are also asked to 're-visit' their original posters, produced during the first few lessons, and reflect on ways in which their ideas have moved on since then.

COMMENTARY

ALTERNATIVE APPROACHES

Students bring with them to their science lessons their own ideas about the nature and behaviour of matter. These ideas have been constructed by individuals through their interactions with the physical and social environment. Learning is seen as a process of conceptual change, whereby individuals consider and evaluate their existing ideas and may change them in the light of experience. Such a view of how learning occurs recognises the **active role of learners**, as only they can bring about change in their own ideas.

Students' ideas can also be elicited using **OPEN ENDED DIAGNOSTIC QUESTIONS**. **DISCUSSION OF RESPONSES** given by other students ...

SOME STUDENT IDEAS

How does the smell get from an air freshener to your nose?

- Smell is lighter than air so it floats.
- Smell molecules stick to air molecules.
- Air pulls the smell out of the air freshener.
- The air freshener smelt because I opened it and let out the trapped smell.

Air freshener

Most students soon realise, however, that the data in front of them does not, itself, provide the answer to the mystery and that it is necessary to make an **imaginative leap** in moving from the clues (data) to their solution to the murder (their theory).

Alternatives include simple **WORD GAMES** looking for patterns and rules, 'black box' activities, consideration of the criteria which students use to judge theories.

What is it about a solid that makes it a solid? **INDIVIDUALS** or **SMALL GROUPS** put forward their ideas on the properties of matter and through **CLASS DISCUSSION** a consensus is reached about the pattern of properties of solids, liquids and gases.

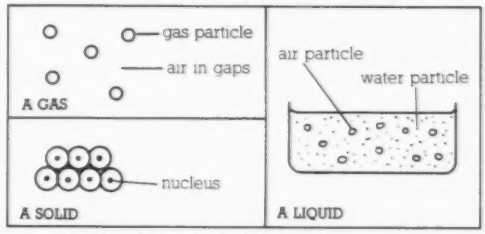
SOLIDS, LIQUIDS, GASES: ONE CLASS'S IDEAS

	Solid	Liquid	Gas
Heaviness	heavy or light	heavy or light	light
Strength	strong	little strength	none
Squashiness	none	a little/none	a lot
Shape	fixed	shape of container	spread

At no point in the introduction to this lesson does the teacher explicitly refer to particulate theory.

Ideas on **POSTERS** will range from macroscopic to several different versions of particulate theory. Initially the teacher makes little input to discussion, allowing **STUDENTS TO LEAD THE DISCUSSION** about the relative merits of the various theories.

IDEAS FROM POSTERS INCLUDED THE FOLLOWING



- Particles expand when heated.
- There are no particles in solids or liquids.
- When ice melts the particles melt.

Possible ways of doing this include diffusion **DEMONSTRATIONS** (to introduce the idea of movement of particles), **PRACTICAL ACTIVITIES** in which students can participate (change of state experiments with ice, water, napthalene, wax), opportunities for pupils to think and reflect on the various ideas which have been put forward, use of physical models of the particulate nature of matter. It is essential at this stage that the teacher does not slip back into a transmission mode of teaching. Simply telling the students what the accepted theory is, without providing them with opportunities to reflect on it, is unlikely to lead to them making the desired conceptual changes which would bring about real understanding of at least some aspects of particulate theory.

Many students find the idea that there is **nothing** between the particles in a gas a very difficult concept. The teacher may wish to pursue this issue by providing students with opportunities to **DISCUSS THEIR OWN VIEWS** of what they think is found in between gas particles. By discussing with them the nature of a vacuum and by using **DEMONSTRATIONS** (e.g. diffusion of bromine in a vacuum), the teacher may encourage further thought and discussion.

To this end, the final lessons of the teaching sequence could include **PRACTICAL ACTIVITIES** to consider other simple phenomena such as melting, dissolving, conduction of heat, etc.

Students' **CREATIVE WRITING**, further **DISCUSSION** and **POSTER WORK**, and use of open ended **DIAGNOSTIC QUESTIONS** are other possibilities.

COMMENT AND SUMMING UP

By the end of this section of work it is hoped that the class will have reached a consensus about its version of the particulate theory of matter. Within each class, individuals will have changed their ideas about matter by varying amounts. Thus, one student's understanding of the 'class consensus' may not be the same as that of other students. It is intended that this sequence of lessons should serve as an introduction to particulate theory and it is hoped that students will be given further opportunities in later science lessons to build on their understanding of the theory as applied in a range of contexts, e.g. transport in Biology, many aspects of Physics and Chemistry to 16+.

What do students think about this approach?

- The lessons made me think about items which I'd usually taken for granted.
- It's not very often in class discussions that somebody says something and nobody laughs – it was good.
- I think being left alone to work out the problems was better for me than just being told.

This approach to teaching places emphasis on learning as conceptual change, and on the active involvement of the learner in the learning process. It raises several general issues for science teachers:

- the amount of time which is needed if students are to be given real opportunities to consider and try out new ideas.
- the role of **APPROACHES** other than classical practical experimentation in science lessons.
- the role of the teacher in science lessons; a move away from being simply provider of the 'right answer'.

Such an approach may represent fundamental change in teaching style for many science teachers.

Some reactions from teachers involved in trials of the teaching sequence

- It's hard work for me, being aware of all the different ideas the kids bring and adopting a different style of teaching.
- I felt that I talked more than I had intended... I was **instructing** too much.
- It occurred to me that heavy demands were being placed on the class, to make up original theories, take part in meaningful discussion, concisely record ideas.
- I've enjoyed the last seven weeks!

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by the Children's Learning in Science Project. The detailed teaching scheme (*Teaching the Particulate Theory of Matter from a Constructivist Perspective* produced by The Particle Working Group, CLISP.) containing exemplars of student work and feedback from teachers, is available from: The Business Secretary, Centre for Studies in Science and Mathematics Education, The University, Leeds LS2 8JT.

Ideas about learning

Driver, R. and Bell, B. Students' thinking and the learning of science. *School Science Review*, March 1986

Students' ideas: general

Driver, R., *The Pupil as Scientist?* Open University Press, 1983
Driver, R., Guesne, E. and Tiberghien, A. (eds) *Children's Ideas in Science*. Open University Press, 1985
Osborne, R. and Freyberg, P. *Learning in Science*. Heinemann, 1985

Students' ideas: particles

Brook, A., Briggs, H. and Driver, R. *Aspects of Secondary Students' Understanding of the Particulate Nature of Matter*. Centre for Studies in Science and Mathematics Education, University of Leeds, 1984

Wightman, T. in collaboration with Green, P. and Scott, P. *The Construction of Meaning and Conceptual Change in Classroom Settings: Case Studies on the Particulate Theory of Matter*. Centre for Studies in Science and Mathematics Education, University of Leeds, 1986

Workshop

Brook, A., Briggs, H. and Driver, R. *Aspects of Secondary Students' Understanding of Particulate Matter: Workshop Pack*. Centre for Studies in Science and Mathematics Education, University of Leeds, 1985

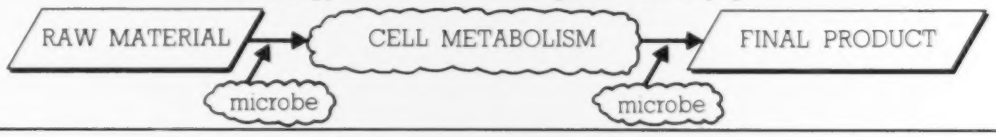
Educational broadcasting materials

Yorkshire Television: *Scientific Eye* has three programmes relevant here for 11 – 13 year-olds, namely *Lighter than Air*, *River of Rock* and *Drying Out*.

YOGHURT AND YOU

PURPOSE

The purpose of this exemplar is to develop an understanding of the biotechnology associated with the production of yoghurt.



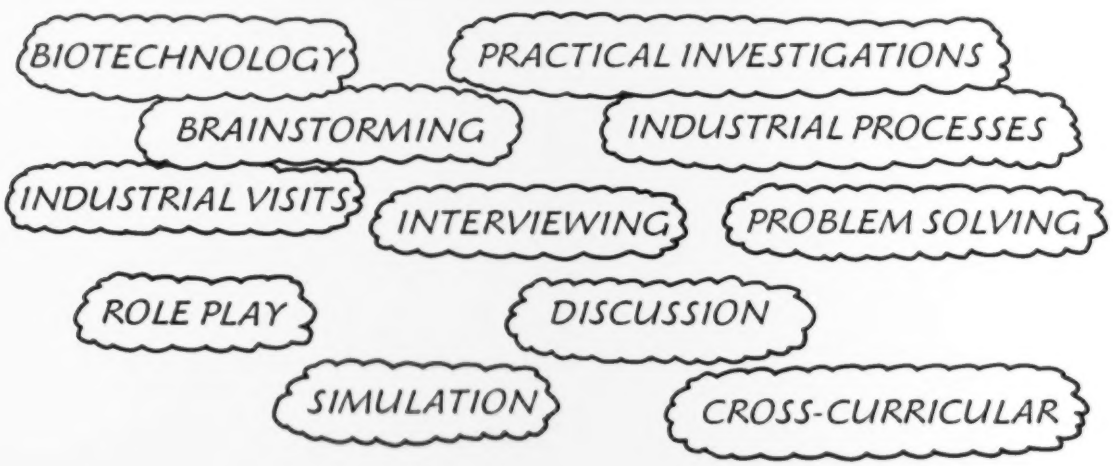
SYNOPSIS

Students are presented with **PRACTICAL INVESTIGATION** to study the metabolism of the microbes involved and are asked to consider **PROBLEMS** associated with the industrial preparation of yoghurt. Finally students are asked to consider the influence of **consumer** needs on the process and to take these into account in the **LABORATORY INVESTIGATION**.

The teaching materials have specific aims such as:

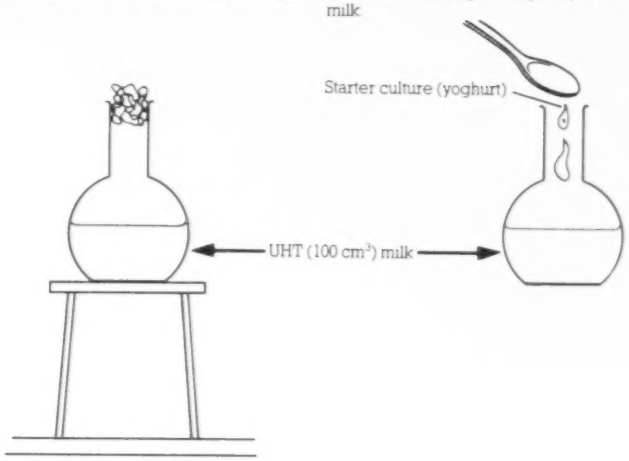
- to involve open-ended approaches;
- to encourage the consideration of social and economic factors;
- to encourage social and problem solving skills;
- to consider how industrial processes can be **SIMULATED** and scaled down to laboratory investigations;
- to provide an enjoyable learning experience and to demonstrate that science can be fun;
- to demonstrate the interdisciplinary nature of real life technological problems.

Three main approaches are commented upon and described in the abstract: **ROLE PLAY**, **BRAINSTORMING** and **READING FOR UNDERSTANDING**. The teacher notes emphasise that the material is a resource to be used alongside a wide range of other approaches which cannot be included here due to shortage of space.



WAY IN

What is yoghurt? The students are presented with a brief description of the action of lacto-bacteria on milk and the production of lactic acid. **PRACTICAL INSTRUCTIONS** are given diagrammatically and by brief written notes. The 'starter' is left for some time and then added to a number of sterile beakers (use a microwave or bisulphite crystals) containing fresh milk.



A. Heat (100 cm^3) of UHT milk to 40°C
B. Add one teaspoon of yoghurt
C. Incubate overnight at 40°C

The **INVESTIGATION** continues to monitor the level of lactic acid and to determine what is involved in the production of an 'eatable' yoghurt. A set of possible ideas for **PROBLEM SOLVING** are given in the teacher's guide:

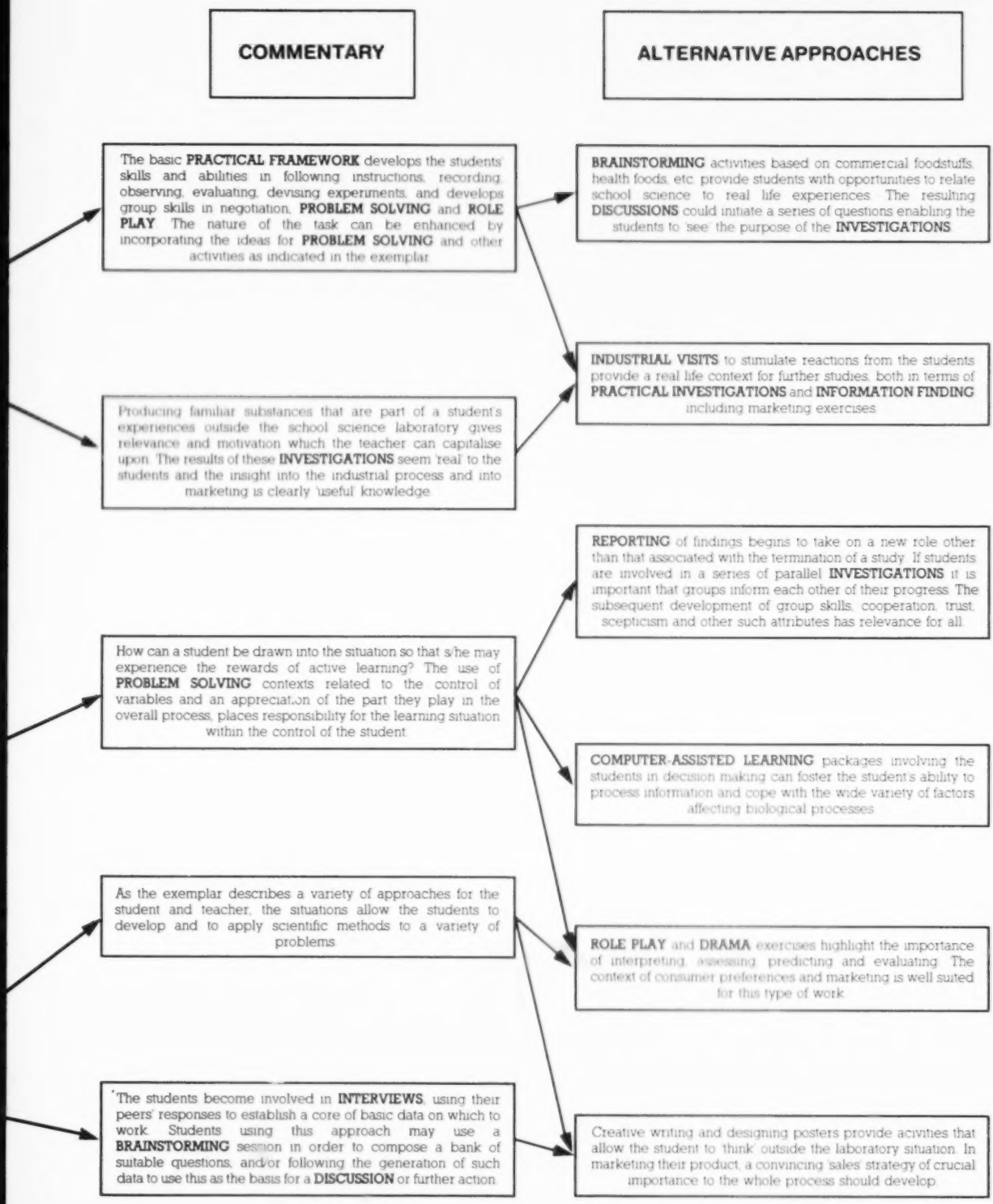
1. The faster an attractively textured yoghurt is made, the greater is the cash return. Find optimum ways (temperature, type of milk, quality of starter culture, etc.) in which rapid lactic acid formation is encouraged.
2. Find ways of lengthening the 'shelf-life' of yoghurt.
3. Find out if the percentage of fat in the milk affects the rate of set or the final consistency of the yoghurt.

A range of activities tied to an understanding of the whole purpose of the activity is offered:

1. Find out which thickness of yoghurt is visually most appealing (**CLASS OPINION**).
2. Suggest ways to increase the sales of yoghurt – the need to identify present consumption levels is recognised and a **CLASS SURVEY** is undertaken. The students can then consider the variety of uses for yoghurt.

It is suggested that students should find out how many of their fellow students eat yoghurt: daily; in flavoured sweets; in ice cream; in milk shakes and whips, etc....

The notes continue by indicating ways in which students can view the information and use it to produce a basis for further study.


COMMENTARY
ALTERNATIVE APPROACHES
The basic PRACTICAL FRAMEWORK develops the students' skills and abilities in following instructions, recording, observing, evaluating, devising experiments, and develops group skills in negotiation, PROBLEM SOLVING and ROLE PLAY. The nature of the task can be enhanced by incorporating the ideas for PROBLEM SOLVING and other activities as indicated in the exemplar.
BRAINSTORMING activities based on commercial foodstuffs, health foods, etc. provide students with opportunities to relate school science to real life experiences. The resulting DISCUSSIONS could initiate a series of questions enabling the students to 'see' the purpose of the INVESTIGATIONS.
INDUSTRIAL VISITS to stimulate reactions from the students provide a real life context for further studies, both in terms of PRACTICAL INVESTIGATIONS and INFORMATION FINDING including marketing exercises.
Producing familiar substances that are part of a student's experiences outside the school science laboratory gives relevance and motivation which the teacher can capitalise upon. The results of these INVESTIGATIONS seem 'real' to the students and the insight into the industrial process and into marketing is clearly 'useful' knowledge.
REPORTING of findings begins to take on a new role other than that associated with the termination of a study. If students are involved in a series of parallel INVESTIGATIONS it is important that groups inform each other of their progress. The subsequent development of group skills, cooperation, trust, scepticism and other such attributes has relevance for all.
How can a student be drawn into the situation so that s/he may experience the rewards of active learning? The use of PROBLEM SOLVING contexts related to the control of variables and an appreciation of the part they play in the overall process, places responsibility for the learning situation within the control of the student.
COMPUTER-ASSISTED LEARNING packages involving the students in decision making can foster the student's ability to process information and cope with the wide variety of factors affecting biological processes.
As the exemplar describes a variety of approaches for the student and teacher, the situations allow the students to develop and to apply scientific methods to a variety of problems.
ROLE PLAY and DRAMA exercises highlight the importance of interpreting, assessing, predicting and evaluating. The context of consumer preferences and marketing is well suited for this type of work.
The students become involved in INTERVIEWS, using their peers' responses to establish a core of basic data on which to work. Students using this approach may use a BRAINSTORMING session in order to compose a bank of suitable questions, and/or following the generation of such data to use this as the basis for a DISCUSSION or further action.
Creative writing and designing posters provide acivities that allow the student to 'think' outside the laboratory situation. In marketing their product, a convincing 'sales' strategy of crucial importance to the whole process should develop.

COMMENT AND SUMMING UP

In the context of any activity it is likely that a student will enter a **PROBLEM SOLVING** mode and ask the first and most natural question, 'Is the problem mine?' The resulting answer may well affect that student's motivation considerably and it is a question which *must* be addressed if the 'learning situation' is to be effective and the student shares/sees the purpose of the study.

A few notes on the board would provide the students with information of the processes involved, yet the vast majority of teachers would wish to do more than this. We need to foster a whole series of approaches that actively involve the students in their own learning and develop the ideas and abilities essential both as a basis for further learning and for life beyond the school situation.

Following this theme it is important to consider a more frequent use of **VISITS** to farms, factories and other situations where the sales/marketing procedures highlight the link between education and industry, providing a sense of reality for the students who themselves may well seek employment or training as a result of such experiences.

Studies such as the biotechnology exemplar, based here on the theme of food and food preservation in an historical or cultural context, underline the importance of a **CROSS-CURRICULAR** approach as a means of providing a relevant and meaningful learning situation for young people in school.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar supplied by B. Godding (SSCR) *Developing Modules on Biotechnology for 11 – 14 and 14 – 16 year-olds*. Additional exemplar material from R. Phipps, (SSCR) *Biotechnology Modules for 16+ Courses*.

Other relevant materials from:

Millard, A. *et al. Biotechnology. A teacher sourcebook of experiments and evaluations of curriculum materials*. Wiltshire LEA, 1986. Contains experimental details and an excellent survey of multi-media resources available to teachers with their suitability for specified target groups of students.

NEA GCSE *Science* (MODULAR); Enzyme Technology/Food Technology.

It's No Accident, a science-based dance presentation on the food industry and its effects on those who eat and those who are hungry across the world. Available from LUDUS, 6 Thurnham Street, Lancaster LA1 1YUD (Tel: 0524-35936).

Pyke, M. *Food Science and Technology*, 4th edn, John Murray, 1981.

Williams, I. W. *Third World Science Project* has some useful biotechnology packs. Infomation from Professor Williams at The School of Education, University College of North Wales, Bangor, Gwynedd.

BBC Education materials with broadcast dates:

Science Topics (TV), *Catalysis*, Autumn 1986.
Science Topics (TV), *Biotechnology*, Autumn 1986.
Biotechnology (Radio Night Time Broadcasts), Summer 1987.

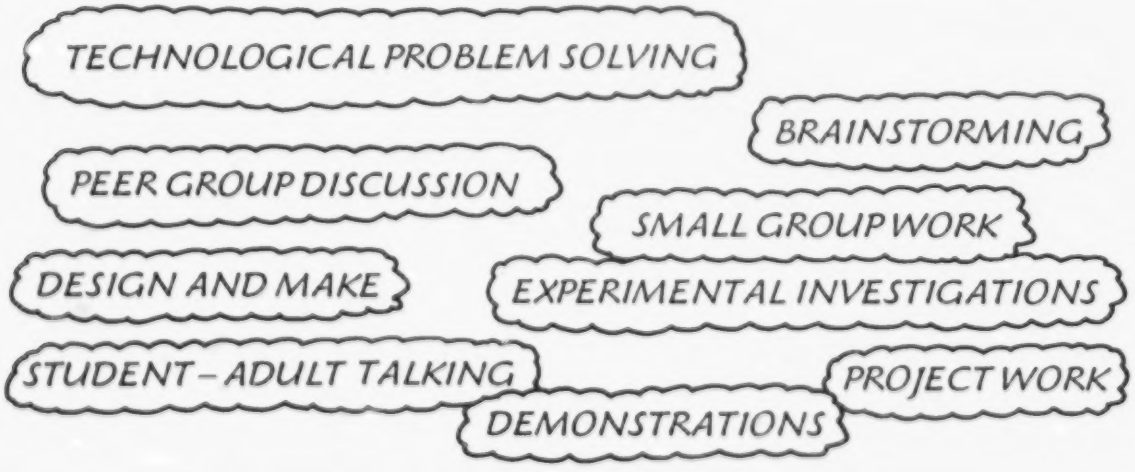
ELECTRICITY, ELECTRONICS AND MICROELECTRONICS TECHNOLOGY PROJECT

PURPOSE

To show ways of developing more effective understanding of electric circuits, by students creatively **BUILDING AND CONTROLLING** models. To understand the differences between scientific and technological processes and to gain experience of using them.

SYNOPSIS

The Cheshire SSCR working group TEEM project (Technology through Electricity, Electronics and Microelectronics) provides an approach to teaching electricity, electronics and microelectronics to pupils in the 11 – 13 age range through creative **PROBLEM SOLVING ACTIVITIES.** The first part of the course is intended to complement or replace the exisiting electricity unit found in many science schemes and in addition to develop a student's technological skills, inventiveness and the ability to work as part of a team. Concepts of circuits are developed through a mixture of **EXPERIMENTS** and structured **CONTROL ACTIVITIES** using Fishertecnic or Lego models. The exemplar describes a lesson part way through the first-year work on electric circuits with 11 – 12-year-old students. They have already **INVESTIGATED** components and connected them in series and parallel.They have built and controlled a single motor vehicle, using a micro-switch, a reed switch, a mercury tilt switch and an on/off switch in a series of design activities. At the end of the course students will do a **PROJECT** of their own choosing but are not yet used to the process of 'analyse – design – test – select – build – evaluate'. In this exemplar a **STRUCTURED PROJECT** to build a lighthouse is used to develop the processes of thought and action characteristic of the design process. Students have a concrete example on which to base their concepts of circuits and switches. This has proved effective with all abilities. Following this lesson students will **INVESTIGATE** resistive control, electric current and computer control which provides an electronic 'mirror' to this project before doing a final project of their own choosing.



BUILDING A LIGHTHOUSE (100 – 140 mins)

WAY IN

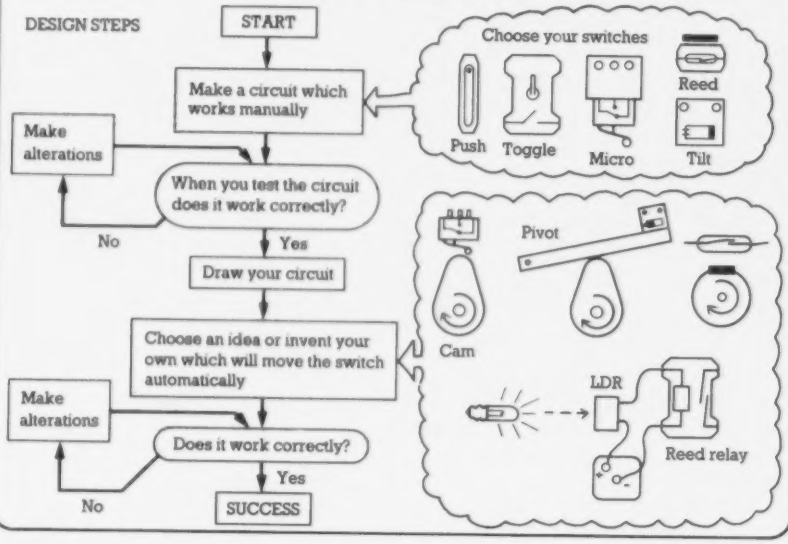
The **PROBLEM** is to devise a flashing mechanism for a lighthouse and also to include a fog siren which can be switched on to sound at the same time as the light flashes.

An **INSTRUCTION SHEET** is used to focus students' attention on the **PROBLEM SOLVING** activity and to make sure that the students are continually reminded of the processes involved. A **FLOWCHART** is used to illustrate the process. Some possible switching mechanisms which could be adapted are **DEMONSTRATED**. The teacher starts the lesson by introducing the problem using the sheet reproduced below.

PROJECT – A LIGHTHOUSE

SPECIFICATION

You have to make a lighthouse control system which flashes a light on and off continuously. A buzzer should also be used as a fog siren which sounds when the light is on and is controlled by a separate switch.



The **REPORT SHEETS** are then handed out and students reminded that they will have to **RECORD** information in rough as they do the project so that they can complete the report at the end.

Students are already familiar with the equipment so no explanation is needed here and they are in established working groups. The teacher suggests that the group think of different ideas in a **BRAINSTORMING** session and then each member of the group (two or three) tries out one or more ideas. After about 20 minutes each group should be testing their ideas and noting the good and bad points by **observation** and **recording**.

Having decided which design is the 'best' the model is made with the work split between members of the group. Building a reliable working model can take longer than teachers or students think, so 30 – 45 or even 60 minutes should be allocated for this process which requires the use of **manipulative skills**.

When all models are built they are clearly labelled and students gather around the front, decide on what tests can be used and then test each one. The results are **DISCUSSED** and a vote taken on which was the 'best'.

Sufficient time should be allowed for students to draw a diagram of their model and to complete the **REPORT**.

Take the models apart and pack away. Ask the students to start filling in the **REPORT SHEETS** and finish for **HOMEWORK**.

COMMENTARY

ALTERNATIVE APPROACHES

Students cannot learn how to **SOLVE PROBLEMS** by watching. The approach taken allows students the freedom to explore their own ideas but gives teachers a structure within which they are confident. The lesson uses no 'new' circuits. The electrical solution has been met in previous lessons but not in this exact form. This project adds a **DESIGN CONTEXT**.

One of the difficulties is in introducing students to the problem without solving it for them. This is particularly true with this problem because it has only a few fundamentally different methods of solution.

Pose the **PROBLEM** of the electrical circuit as a **HOMEWORK EXERCISE** set in the context of a lighthouse. Arrange for a pack of ideas, including some actual ways lighthouses work, to be available in the school library so that students have an information base from which to work. Some students may then see the possibility of keeping the light on continuously with a tube rotating around it with a hole on one side. Their paper designs can than be made in the usual way.

Most students have little difficulty in thinking of solutions and have support from the ideas on the sheet. They do have difficulty making their idea work and this shows them one of the differences between science and technology. It is not sufficient to know **how** to solve the problem. Actually having to make the solution work develops a whole range of skills which would not normally be developed if a **TECHNOLOGICAL APPROACH** were not made.

The **REPORT SHEET** contains space for the electrical circuit diagram, for a drawing of the mechanism used to make the lamp flash, for students to explain why they chose their particular solution and to describe how the flashing time could be altered.

Give the pupils a set of designs drawn on paper and ask some **COMPREHENSION TYPE QUESTIONS** on them designed to draw out the advantages and disadvantages of each design.

The **BRAINSTORMING** session allows **all** members of the group to contribute. An essential aspect of **PROJECT WORK** is to try to anticipate the material needs. These are kept to a minimum here because the contents of the kit are limited and only scissors and card are needed as extras. It may help if the groups are single sex or the boys tend to dominate. The teacher's role is to move from group to group getting students to talk about their ideas and progress and taking a non-directive role through **PUPIL – ADULT TALKING**. Suppress the need to rush on. This sort of work takes time, as soon becomes apparent having done the project work yourself **in advance of using it with the students**.

The work provides a link between conventional science and CDT activities and some aspects of the project (e.g. cam making) can flow over into the CDT work. It might also be possible for them to **DESIGN AND MAKE** a proper working model in CDT.

Each member of the group will probably think their idea is the best and so **negotiation** and **agreement** is needed because only one idea can be built in the time. Be prepared for students to ask questions about what 'best' means. Lead them to set a parameter which the design must meet, i.e. smallest possible size, ability to alter the time the light is on for easily, using the smallest number of parts. One of the purposes of this piece of work is to enable students to appreciate the importance of setting criteria on which to judge a design.

Make a set of working models, two or three for each design, but each with different design faults. Get each group of students to test each model in turn and list the advantages and disadvantages, producing a list of criteria on which judgements may be based. This can take quite some time in preparation but does allow students' minds to be concentrated on analysing what the device actually does. There is a danger with **PROJECT WORK** that the building of a working model is seen as the only goal.

Students at this age like an element of competition. Draw out that to decide on the 'best' there must be a standard. Are they just looking at the fact that it works or are factors such as the amount of materials used and the appearance taken into account. These are technological factors, not scientific ones. **DISCUSS** with students the length of time the lamp flashes as part of the cycle. Someone is likely to suggest altering the shape of the cam so have some thick card, scissors and blu-tack available. You may wish to set a precise problem on timing.

This can cause difficulties since a 3-D view is best. The teaching pack contains 3-D diagrams of the parts which students can draw over with tracing paper.

COMMENT AND SUMMING UP

A good **PROJECT** should set the educational activity in a context which has relevance for all students. This is a tall order, but if the learner is not interested in the activity then the learning is likely to be at a low level. It is worth spending some time developing the learning context through a variety of stimulatory experiences. To support this project on a lighthouse a **VISIT** may not be feasible but many students will have seen lighthouses during holidays and **learner's own experience** can be drawn on. It is probably also worth asking the Humanities department if they have any **VIDEO MATERIAL** on the coast or navigation to provide background information and to set the scene. It may be felt that building a lighthouse does not appeal to everyone, in which case alternatives could be used. One similar idea is the flashing light on a pelican crossing or railway level crossing. Both these examples have the potential for further development as a **STUDENT'S MAIN PROJECT**. In selecting an alternative it is important that:

1 There are only about four essentially different solutions;
2 The solution can be constructed with the kit used;
3 It is feasible to build the device in the time available.

Very few ideas are truly original and new initiatives normally arise through new combinations of previous experience. It is very easy for the teacher to take ideas for granted and not see that even simple ideas are a new experience from the student's viewpoint. Ideas sheets have tremendous potential providing that they do not give the complete solution. The **analysis** of the problem is very important because the learner must have a clear idea of what the final outcome should achieve.

It is always difficult to compare the solutions from different groups when the problem is relatively simple, but students do have another project to do through which they can show individual flair. The link between Science and CDT is important and this type of project could be used to forge links if none exist. Possible strategies for collaboration could include:

CDT Start designing the tower and the flashing pattern of the light using information about lighthouse flashing patterns and photographs if possible.

Science Design the electrical circuit needed. Solve the problem of the flashing pattern needed using the construction kit.

CDT Design and make a cam out of perspex with a fitting to attach to the Fischertechnic or Lego shaft.

Science Fit the cam and test out. Make any minor alterations needed. Explain how the circuit works.

CDT Fit the design inside the finished model of the lighthouse. Write the report, including careful drawings.

REFERENCES, WORKSHOPS AND RESOURCES

Exemplar TEEM (*Technology through Electricity, Electronics and Microelectronics*) supplied by Trevor Cross of Great Sankey County High School, Cheshire in collaboration with Andy Cooper, formerly a SSCR Cheshire Convenor and now with the British School Technology, Trent Polytechnic.
TEEM, Parts 1 and 2, Cheshire County Council, 1987

Other useful materials include:

Legotechnic II Set 1032
Legotechnic II Extra Activity Cards 1033
Teacher's Guide to Technic II 1036
Activity Guides in Fischertechnic Kits UT1 and UT2
Schools Council Modular Courses in Technology *Mechanisms*, available as an Introductory Pack comprising one copy each of Teacher's Handbook, Students' Handbook and Students' Workbook, Oliver & Boyd, 1981
Electronic Systems News, a quarterly periodical produced by the Institute of Electrical Engineers and available to all schools through every Local Education Authority
Unilab MFA Appraisal Pack 540 105
Microelectronics Education Project MEP/MIT files - details from Mrs B Bevis, 'Ronsella', Lordswood, Highbridge, Eastleigh, Hants.
In-Service Training Courses for Science and CDT Teachers further information and details from British School Technology – Trent, BST/NCST, Trent Polytechnic, Burton Street, Nottingham, NG1 4BU (Tel. 0602 418248 ext 2101)

BBC Education materials with broadcast dates

Technology and Design (Radio and TV), Spring 1987
Mindstretchers (TV), Summer 1987
Microelectronics in Action (TV), Summer 1987

SECTION FOUR

Monitoring students' progress and teachers' effectiveness

Introduction

This section focuses upon two of the questions raised in the introduction:

- how can students' progress in learning be monitored?
- how can teachers' effectiveness in providing enhanced learning opportunities/outcomes be evaluated?

This section makes suggestions for finding out if new approaches have been successful, for youngsters, for teachers and for achieving the agreed purposes.

What are the benefits to the students?

Earlier sections painted a picture of science education as a broad, balanced and essentially relevant experience in which young people were active partners. The benefits to the students should be more than just conceptual understanding or learning skills. Figure 1 provided a framework for science education whereby young people have a hand in devising the questions for investigation, the methods of answering these and in selecting appropriate reporting procedures. The implication is that thereby youngsters may become more autonomous, more self-directive and more competent. An example is given below of a change in teaching approach with an analysis of the achievements of the teachers and young people involved. This evidence forms the basis of a checklist presented below in *What can be learned from their comments?* of aspects which might be used by teachers to monitor youngsters' progress.

Initiating problem solving

One school in Cambridgeshire organised a whole problem-solving day for the second-year*. Normal science classes were taken by other departments and the second-year were given the whole day in the department to work on their selected problems. They were allowed free choice from a range of problems set out in the rooms of the department and were then required to work on their choice. A further choice was permitted until breaktime, after which the youngsters had to remain committed to their chosen problem. Science department staff were available as consultants, managers, resource providers, experts, analysts, and general helpers. The youngsters were asked to report back and were given a questionnaire to fill in anonymously at the end of the day.

What did the young people and their teachers feel they gained?

A commitment to science as an interesting and worthwhile experience

The youngsters comments included:

I enjoyed the day so much that I spent all but thirty minutes working.

I'm not great at science but it made me think for myself and try different experiments. It was better doing the experiments yourself rather than watching the teacher going through it.

Teachers said:

. . . many children came back early at lunchtime to continue their work.

there was some question as to whether the children had actually learnt any science, but it was felt that an awful lot of scientific knowledge was being ***put into practice*** *and that this was very important.*

A greater awareness of the demands of working cooperatively

Many young people mentioned this aspect.

. . . work with a team and be patient.

I think it would be a good idea for other children to have a go because you learn to work in a group and listen to other people's ideas instead of pushing your own ideas forward.

Teachers had similar views:

the cooperation in the groups was excellent in most cases.

* Details from Dave Wallwork, Deputy Headteacher, Ailwyn Community School, Ramsey, Cambridgeshire.

Having the opportunity to plan and think for themselves

This was not an aspect that teachers picked out as being important at the time, but for the youngsters it was something they enjoyed greatly.

> *I most enjoyed having to think and order equipment for myself.*
>
> *I have learnt that if I put my mind to it I can make up some good ideas.*
>
> *It taught us that school isn't just 'Sit down', 'Be Quiet' and 'Do as you are told'. There is much more to it than that.*

Experiencing science as 'fun'. A sense of enthusiasm and enjoyment

For instance youngsters said:

> *I think we should do more of these. They were good fun and quite educational!*
>
> *I think it was a good day and a lot of fun. I learnt a lot about metals and the way of combining different separation methods in one machine.*

This aspect, coupled with a sense of purpose in achieving something worthwhile, was an important one for teachers too.

> *children were well motivated, sensible and enthusiastic and there was purpose in their work.*
>
> *even the trouble-makers among the children were enthusiastic and well motivated. It was thought that perhaps this might be a true measure of the success of the day.*

What can be learned from their comments?

Generalising from a specific example, even one as wide-ranging as problem solving, is difficult. Some of the things youngsters gained from the activity cannot necessarily be applied to other approaches. Nevertheless, there are aspects in this example which teachers might look for in all approaches and use as indicators of the involvement young people have with the approach being used. These are outlined below with some brief exemplification.

- Enthusiastic youngsters: happy, busy people who want to discuss their science.
- A commitment to the work in hand: working through break; turning up early for the lesson.
- Well-motivated youngsters: 'trouble-makers' involved; a relaxed atmosphere in the classroom.
- Self-directed young people who initiate their own work and carry it through: persevering with the task; not giving up; being prepared to adapt and change the original plans in the light of difficulties; seeking further information for themselves.
- A sense of purposeful activity which is maintained by the efforts of the students: work not always teacher-directed; students suggesting and trying out their own paths; taking responsibility for their own actions and reports.
- Cooperation and teamwork in the class: being prepared to listen to the ideas of others and value them; being prepared to enter into meaningful discussions that focus on an issue and follow it through.

There are of course many other things that young people learn whilst doing science, not the least of which are skills, concepts, and an awareness of different attitudes to issues. These are obviously aspects that teachers will look for when monitoring students' progress. No new approach would be worth consideration, however enthusiastic the students, if they had learnt no new skills, concepts or attitudes as a result! There are increasingly sophisticated methods for monitoring progress in such areas, but we feel that it is not the brief of this booklet to deal with such issues. The accompanying Curriculum Guide **Better Science: Assessing progress** in this compendium contains a wealth of such advice.

What are the experiences of other teachers using new approaches?

Any learning situation that has numbers of young enthusiastic people in it, in combination with a manager who is unsure of the precise outcomes, has the potential to be many things. It is not however one in which to 'light the blue touch paper and stand well back'. The experiences of teachers in the working groups indicate that trying out new learning approaches in the classroom for the first time was not easy. There were several occasions when they felt distinctly 'out of control'. Despite the students' enjoyment of the experiences, the teachers' own reassessment was that this was an approach that was fine once in a while, but not something they would care to repeat on a regular basis. For instance, one teacher, who had tried some work in Cambridgeshire on a problem-solving approach (**4.1**), when asked what had been gained from the topic said:

> *It was very hard work, exhausting, but I now have more insight into how children think and ideas on how children work without specific guidance from an adult.*

In another example, teachers from a science department in Portsmouth (**4.2**) had developed a

unit of work which focused on communication as a cross-curricular study. This meant cooperating with other school departments and working with outside agencies. They also tried out the use of video cameras in their lessons. The whole project lasted several weeks. Box 3 summarises the outcomes.

Successes:

- everybody agreed that the cross-curricular links were a big plus. They boosted staff morale, improved staff relationships and brought out the best in people.
- people became aware of the resources available in the school as a whole (although the lack of full use of modern equipment in the school was highlighted!)

Failures:

- most felt the lack of time available to develop their ideas to the full constituted a 'failure'.
- in some cases the feeling of lack of specific 'expertise' made one or two people feel that they had not done full justice to their work.

Box 3 *A catalogue of successes and failures*

What can be learnt from this? That any change in teaching approach is difficult, time consuming, exhausting, often frustrating and sometimes threatening to teachers' ideas of 'being in control'. That it is often accompanied by feelings of failure and an ever-present sense of unease. Teachers have also described changes in approach as rewarding, helping them to learn, and a focus for improved relationships with young people but, more importantly, have emphasised the real sense of achievement — and that it is not gained overnight. Furthermore, careful evaluation of the success of the technique is required, over a period of time, and from a number of points of view.

What methods could be used to collect the evaluation evidence?

There are two aspects of the evaluation process, one relating to the teacher and one to the learner. Evidence about the viewpoint of the students could be collected by means of a questionnaire. The viewpoint of the teacher as to how the approach is working is necessarily different. Whilst some of the indicators mentioned at the beginning of this section in *What are the benefits to the students?* will be valuable as impression markers of youngsters' involvement, more careful collection of evidence is also necessary. Some suggestions of methods that could be used are shown in Box 4.

- Keeping a diary of events which happened in the classroom. This may be at the level of successes and failures, as the Portsmouth group did. It may be simply notes on what the youngsters did or things to change next time round. It is important to write notes soon after the events, while the impressions are still fresh in the mind. If the diary is written on several trials of the approach, then it provides an interesting way of comparing the changes in style, and viewpoint, or levels of success and failure as the trials progressed.
- Inviting another member of the department in to observe the lessons. Obviously this needs to be some trusted colleague who understands the purpose of the innovation. It may be best initially to devise a set of specific things to look for, things that the teacher is unsure about for instance, so that both teacher and observer have objectives in mind. On the other hand, there are often very exciting things going on in lessons which, as managers, teachers may miss completely. Roving observer colleagues are ideally placed to pick up these unexpected bonuses.
- Recording the youngsters' discussions. Teachers cannot be party to all the discussions of a group. One useful idea is to ask the youngsters to leave a tape recorder running on the desk whilst they work. This gives some idea of the quality of discussion and the ideas that youngsters are working through. Teachers who have used techniques like brainstorming and small group discussions have found this valuable in learning which topics stimulated enough interest to keep the youngsters at the task. It helped to alleviate some of their fears that the discussion would simply dissolve into one on last night's television programmes if they were not keeping a constant eye on it.
- Watching other members of staff teach the technique. Colleagues may be experienced or inexperienced. Whichever is the case, it is valuable in helping to provide support for staff development.

Box 4 *Suggestions for collecting evidence*

The teacher as 'action researcher'

Action research is the name given to various techniques through which a teacher sets specific goals or problems to be explored and develops strategies to carry out research to monitor events as they occur in the classroom. Use of techniques such as these reveal a great deal about classrooms and their interactions. Many teachers read the results of work done by professional researchers on classroom interactions, but few actually use the techniques systematically themselves. Yet almost all evaluate their own work intuitively all the time.

We all 'know' when something works well. What we rarely do is stop to analyse *how* we know — what our own criteria for deciding are and what it is that has 'worked'. Careful and systematic recording of progress in using a teaching technique is a valuable tool for the professional teacher. Such tools are part of the 'kit' of the teacher as an 'action researcher'. The teachers in SSCR Local Working Groups have shown themselves to be very skilled action researchers, whose results have been powerful shapers of their practice. Readers wishing to explore this aspect could do so by keeping diaries or detailed field notebooks, making careful observations and recording descriptions of events, by keeping a photographic record for analysis, by using audio-taping techniques for keeping records of class discussions or when conducting interviews with students, or even by using video recordings for subsequent analysis. Teachers wishing to conduct such evaluation exercises and become involved in action research will find detailed advice on the various techniques in Walker's book *Doing Research: A handbook for teachers* (**4.3**).

SECTION FIVE

Ways and means

The main purpose of school learning has been identified in earlier sections as that of increasing the responsibility of young people for their own learning over time, by enabling them to take an active part in the learning process. The ideal to be achieved through the curriculum model described in Fig. 1 is that young people should become more autonomous and self-directive, with the ability to reach their own decisions and to rely on their own judgements. It is recognised that science has aims beyond gaining factual knowledge and developing skills and concepts, and that a prime aim is to develop *competence* in the use of scientific ideas and when interpreting the implications of science and technology for individuals, for industrial concerns, for the environment, for society, and so on. Such competence is an essential prerequisite in developing 'Science for citizenship' whereby young people, as members of a rapidly changing technological society, may become capable of acting to improve the quality of life for themselves and others.

The evidence pointing to the need for a wide range of learning approaches has been reviewed. The extended range of aims as presented by the SSCR (**2.1**) and the purposes for education identified above both indicate the need for an extended range of learning approaches. The recommendations which follow also recognise pragmatic reasons for increasing the repertoire of approaches available to science teachers, such as the need to stimulate and to intrigue the learner and to encourage personal initiative and motivation in ways which cannot be provided by chalk, talk and experiment alone. Furthermore the fundamental importance of *mistakes* as key components in the learning process is recognised, as is the need to involve young people in the definition of the purposes for learning activities. In short, we are advocating a re-orientation of the role of teacher and learner which would result in a raising of the status of young people — recognising their prior knowledge, skills and attitudes and valuing *their* values and beliefs, which thereby become the foundation for purpose-driven learning activities.

These ideas and others are discussed in the main body of this report and in associated **Better Science** Curriculum Guides. The recommendations which follow, whilst relevant to the findings of the SSCR research and development phase as a whole, are specific to this particular Guide.

1 All students should encounter a wide variety of learning approaches in their science lessons. The experiencing of skills and concepts in a wide range of situations, learning approaches and subject areas is essential if such learning outcomes are to become capable of being transferred to new situations and contexts.
2 Learning approaches should be selected in consultation or through negotiation with the learner (see Figs 1–3) and should provide a balance between oral, practical and written tasks.
3 Learning approaches should enable the student to understand the purpose of the learning activity.
4 Learning approaches should be set in a situation which has relevance for both student and teacher.
5 Particular learning approaches should be shaped by particular learning and teaching needs (see Fig. 3).
6 The intended learning opportunities and eventual learning outcomes should be capable of being recognised by both student and teacher.
7 Teachers should endeavour to provide sufficient time for youngsters to come to terms with new skills, ideas and approaches, and be prepared to give time to follow up the results or findings of an investigation 'discovered' by the students but which were not anticipated.
8 Science teachers should be enabled and encouraged by their school management structure to work collaboratively with other science teachers and with teachers from other subject areas to develop the expertise to operate effectively within the extended range of learning approaches. It is suggested that collaboration would be particularly supportive and effective in the early stages of working with a fresh approach and when collecting evidence for evaluating the outcomes, i.e. when the teacher is engaged in action research of any kind.
9 Teachers should be encouraged to work in teams to gain maximum benefit from the available expertise within the science department and throughout the whole school.
10 Teachers should work collaboratively across the whole school curriculum to develop and enhance each others' activities in working with fresh learning approaches.
11 Liaison groups between primary and secondary schools should be encouraged to share information about learning approaches

in common use. Similar links should be forged between teachers of the pre-16 age group and teachers and trainers operating post-16.

12 Teachers should not attempt to work through a new approach at the same time as introducing new skills and/or concepts. Students and teachers cannot expect immediate success when first working with a novel approach, especially if simultaneously working on unfamiliar ground. Inevitably, competence at working with a novel approach develops with practice.

13 Teachers should be enabled and encouraged by the senior management team of their school and by local authority advisers to take action to remove constraints operating on the selection of situation — of school timetable and lack of adequate resource provision.

14 Heads of science departments, headteachers and local authority advisers should recognise the crucial importance of time for teachers to learn about, and become proficient in working with, a range of approaches. There is a pressing need for teachers to have opportunities for in-service training, whether this be school, local authority or institutionally based, which would enable them to try unfamiliar approaches.

15 Science departments, schools and local authorities should develop resource banks comprising detailed descriptions of learning approaches with commentary, alternatives, advantages and pitfalls. The information gathered could be stored and retrieved through data bases using the new technology now available in most schools. Such resource banks could thus be readily up-dated and modified such that 'good practice' could become widely available locally, regionally and nationally.

None of the above recommendations is beyond the reach of readers of this Curriculum Guide. Action can be taken at a number of levels and it may be necessary for teachers to devise strategies to engage heads of science departments, heads of other subject departments within the institution, members of senior management teams in schools, and advisers within local education authorities in continuing discussions on the management of change. It is to be hoped that this Curriculum Guide will spur readers into action and provide colleagues who need to be persuaded with evidence that changes are likely to be beneficial to both teachers and students. The SSCR has shown clearly that individual teachers and members of Local Working Groups are capable of effecting radical change. So now, over to you.

References

The SSCR publications referred to in the text under the series title **Better Science** are not listed here.

0.1 Ellington, E.C. *Approaches to Learning and Teaching: Proposals for consultation*, SSCR, London, 1985

1.1 HMI. *Aspects of Secondary Education in England*, HMSO, 1979

1.2 HMI. *Curriculum 11–16: Towards a statement of entitlement*, HMSO, 1973

1.3 HMI. *Education Observed 3: Good Teachers*, HMSO, 1985

1.4 APU. *Science at Age 11, Science Report for Teachers: 1*, HMSO, 1981

1.5 APU. *Science at Age 13, Science Report for Teachers: 3*, HMSO, 1982

1.6 APU. *Science at Age 15, Science Report for Teachers: 5*, HMSO, 1985

1.7 CLISP. *Aspects of Secondary Students' Understanding of the Particulate Nature of Matter: Full report*, University of Leeds, 1984

1.8 CLISP. *Aspects of Secondary Students' Understanding of Heat: Full report*, University of Leeds, 1984

1.9 CLISP. *Aspects of Secondary Students' Understanding of Plant Nutrition: Full report*, University of Leeds, 1984

1.10 CLISP. *Aspects of Secondary Students' Understanding of Energy: Full report*, University of Leeds, 1984

1.11 CLISP. *Aspects of Secondary Students' Understanding of Elementary Ideas in Chemistry: Full report*, University of Leeds, 1985.

1.12 Freyberg, P. and Osborne, R. *Learning in Science*, Heinemann, 1985

1.13 Driver, R., Guesne, E. and Tiberghien, A. *Children's Ideas in Science*, Open University Press, 1985

2.1 SSCR. *Science Education 11–16: Proposals for action and consultation*, SSCR, London, 1983

2.2 DES. *Science Education 5–16: A statement of policy*, HMSO, 1985

2.3 SSCR. *Towards a Specification of Minimum Entitlement: Brenda and Friends*, SSCR, London, 1984

3.1 Nussbaum, J. and Novick, S. 'Brainstorming in the classroom to invent a model'. *School Science Review*, **62**, 771–778, 1981

3.2 Martin, D.J. (ed. and main author) *MIT INSET Topic Resource Pack 3*: Control*, MIT, 1986

3.3 Simpson, A. (ed. and main author) *MIT INSET Topic Resource Pack 5*: Sensors, instrumentation and analogue electronics*, MIT, 1986

3.4 Nicholls, P. (ed. and main author) *MIT INSET Topic Resource Pack 6*: Electronics in IT Education*, MIT, 1986

3.5 Bulman, L. *Teaching Language and Study Skills in Secondary Science*, Heinemann, 1984

3.6 Davies, F. and Greene, T. *Reading for Learning in the Sciences*, Oliver and Boyd, 1984

3.7 Rudduck, J. (ed.) *Learning to Teach through Discussion*, Occasional Publication No. 8, Centre for Applied Research in Education, University of East Anglia, 1979

3.8 Carre, C. *Language Teaching and Learning: Science*, Ward Lock, 1981

3.9 Sutton, C. *Communicating in the Classroom*, Hodder and Stoughton, 1981

3.10 Barnes, D. *From Communication to Curriculum*, Penguin, 1986

3.11 Nixon, J. (ed.) *Drama and the Whole Curriculum*, Hutchinson, 1982

3.12 Woolnough, B. and Allsop, T. *Practical Work in Science*, Cambridge Science Education Series, 1985

3.13 Solomon, J. *Teaching Children in the Laboratory*, Croom Helm, 1980

3.14 Black, P. and Harrison, G. *In Place of Confusion*, Nuffield–Chelsea Trust and the National Centre for School Technology, Trent Polytechnic, 1985

3.15 Tombs, F. and Allen, G. (eds.) *Problem Solving: Science and technology in primary schools*, The Engineering Council and SCSST, 1985

3.16 DES. *Technology in School Science*, HMSO, 1985

3.17 Lewin, R.H. *A Problem Solving Approach to Science and Technology*, Mimeograph, Berkshire County Council, 1986

3.18 van Ments, M. *The Effective Use of Role Play: A handbook for teachers*, Kogan Page, 1983

3.19 Jones, K. *Designing Your Own Simulations*, Methuen, 1985

3.20 Brandes,D. and Phillips, H. *Gamesters' Handbook*, Hutchinson, 1982

4.1 Howlett, A. *Evaluation of the Desert Island Problem: Comberton Village College*, Peterborough SSCR group, 1986

4.2 Davies, E. *et al.* SSCR group report *Communication. Links across the curriculum*, Hampshire Education Authority, (in press)

4.3 Walker, R. *Doing Research: A handbook for teachers*, Methuen, 1985

* *MIT INSET Topic Resource Packs* are available from 'Ronsella', Lordswood, Eastleigh, Hants.

The Secondary Science Curriculum Review (SSCR) was set up in 1981 to stimulate, through working groups of practising teachers, the development of science studies which would help to provide an appropriate science education for *all* young people growing up in a scientific and technological society — whatever their abilities or career intentions. Its concern was not only with the science curriculum — its contents, purposes, teaching methods and resources — but also with the role of science in general education and within the whole school.

The **Better Science: Curriculum Guides** are based on the combined experience of the Review's Central Team and the working groups. Each Guide deals with a different but significant area of concern. Together they aim to assist teachers both in devising a broader and more balanced approach to science studies and in enhancing their professional development. The intention throughout is not necessarily to provide answers but rather to provoke and encourage teachers' thinking about the various topics addressed.

This Guide, **Better Science: Approaches to teaching and learning,**

- is written by experienced, practising teachers;
- describes, through the use of case studies, ways in which a broad range of approaches to teaching and learning can be used successfully to enhance students' learning in science;
- describes why we need to extend our range of learning approaches;
- provides notes for guidance at a very practical level;
- provides a discussion of implications for students, teachers and education generally.

ISBN 0 435 54821 2

Also available:

Better Science: A Directory of Resources contains details of a broad range of materials produced by local working groups and the Review's Central Team. It includes descriptive and evaluative statements on each piece of material listed.

Better Science: Making it happen summarises, for a wide audience, the thinking of the Review and provides a guide to implementing balanced science for all pupils.

Heinemann Educational Books/Association for Science Education for the School Curriculum Development Committee

Better Science: Key proposals 1
Better Science: Choosing content 2
Better Science: Making it relevant to young people 3
Better Science: **Approaches to teaching and learning** 4
Better Science: How to plan and manage the curriculum 5
Better Science: For both girls and boys 6
Better Science: Working for a multicultural society 7
Better Science: For young people with special educational needs 8
Better Science: Health and science education 9
Better Science: Building primary–secondary links 10
Better Science: Assessing progress 11
Better Science: Learning how to teach it 12